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RESEARCH HIGHLIGHTS

OF THE

NATIONAL BUREAU OF STANDARDS

ANNUAL REPORT

UNITED STATES DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
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Research Highlights
of the
National Bureau
of Standards

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The National Bureau of Standards, Washington, D.C., laboratories (top) and Boulder, Colorado, laboratories (bottom).

Contents

1. General Review

Last year the National Bureau of Standards presented in formal ceremony a set of State standards to the State of Alaska. In the same year, the Director of the Bureau participated in making final recommendations to the General Conference of the International Bureau of Weights and Measures to accept an atomic definition of the meter. These two events indicate the national and international importance of standards activities and the expanding interrelation of these activities among science, industry, and government.

The past year was an eventful one for the Bureau. On the scientific side, it was a period of significant beginnings to new programs and of continued development in important basic programs. Special attention was given to improving standards and measurement techniques in high temperature, pressure, atomic standards of length, and atomic standards of frequency. Advances were made in studies of the molecular structure of alloys, in the determination of microquantities of tritium, and in the characterization of the atmosphere in regions associated with satellite exploration. These activities, and many others, are undertaken in response to growing demands upon the Bureau to advance standards and measurement techniques and to provide accurate data in areas where American scientists are becoming especially active. It is the Bureau's mission [1] to provide the central basis for a complete, consistent system of physical measurement of national scope adequate for the expanding national activity in scientific research. Emphasis in the coming year is expected in the fields of standards and measurement, high-purity materials, plasma physics, and very high pressures.

On the administrative and budgetary side, the Bureau was given an increase in its appropriation to meet the need for strengthening basic research programs and, more specifically, to accelerate research in the field of high temperature. Recognition was given to the pressing need to provide for a higher level of fundamental research with funds provided by the Congress, and to reduce the amount of work done for other government agencies.

This report will present some of the work, studies, and accomplishments of the various laboratories of the Bureau. The descriptions of these activities will be necessarily brief and, in most cases, merely summaries of work which will be fully described in the formal scientific publications of the Bureau.

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[1] The Bureau's responsibilities, as defined by the Congress, may be summarized as follows:

(1) Development and maintenance of the national standards of measurement, and the provision of means for making measurements consistent with those standards;

(2) determination of physical constants and properties of materials;

(3) development of methods for testing materials, mechanisms, and structures, and the making of such tests as may be necessary, particularly for government agencies;

(4) cooperation in the establishment of standard practices, incorporated in codes and specifications;

(5) advisory service to government agencies on scientific and technical problems; and

(6) invention and development of devices to serve special needs of the government.

Technical Activities

As in previous years, the technical program was concerned principally with (1) standards and methods of physical measurement, and (2) precise measurement of physical constants and the basic properties of materials. Other broad areas of effort included radio propagation research, data processing systems, applied mathematics, building technology, and cryogenic engineering. Some of the more important accomplishments of the year are given in the following paragraphs. More complete details of these projects may be found in section 2, page 17 et seq.

Standards and Measurement Methods. To provide basic data and calibration techniques for the rapidly advancing fields of aeronautics and space science, efforts were made to extend precise measurement of both temperature and pressure into increasingly higher ranges. Advances in high-temperature measurement included the extension of the calibration range of optical pyrometers from 2,400° to 3,800° C, construction of a high-current arc as a source of controlled temperatures, and design of a special type of high-temperature resistance thermometer for interpolating between fixed points on the International Temperature Scale. To obtain data for the ultimate establishment of additional fixed points on the pressure scale, equipment was developed and constructed for studying the behavior of various materials at pressures up to 1,500,000 lb/in.^{2} For the calibration of instruments used to measure high transient pressures, apparatus was devised that generates pressure steps of accurately known amplitudes up to 50,000 lb/in.^{2}

In research on atomic standards of length, three devices were developed which provide extremely narrow spectral lines. These narrow lines make possible very precise standards of length based on the wavelength of radiation from mercury atoms. Two of the devices utilize beams of mercury atoms to obtain a line 0.0002 Angstrom in width; the third employs a magnetic filter with mercury-198 vapor to produce an absorption line 0.0003 A wide. Besides serving as sources of very narrow spectral lines, the beam devices were used to obtain more precise information on the properties of the mercury nucleus as seen in the isotope shifts and hyperfine structure of the lines.

Progress was also made in the development of standards of frequency and time based on invariant properties of the atom. A precision of 2 parts in 10 billion was achieved with an atomic clock using a beam of cesium atoms. In other frequency-standard work, hyperfine and Zeeman resonances in cesium and rubidium vapors were investigated. Hyperfine line widths in rubidium as narrow as 20 cycles at 7,000 megacycles were observed. Two rubidium-vapor atomic clocks were under construction using these results.

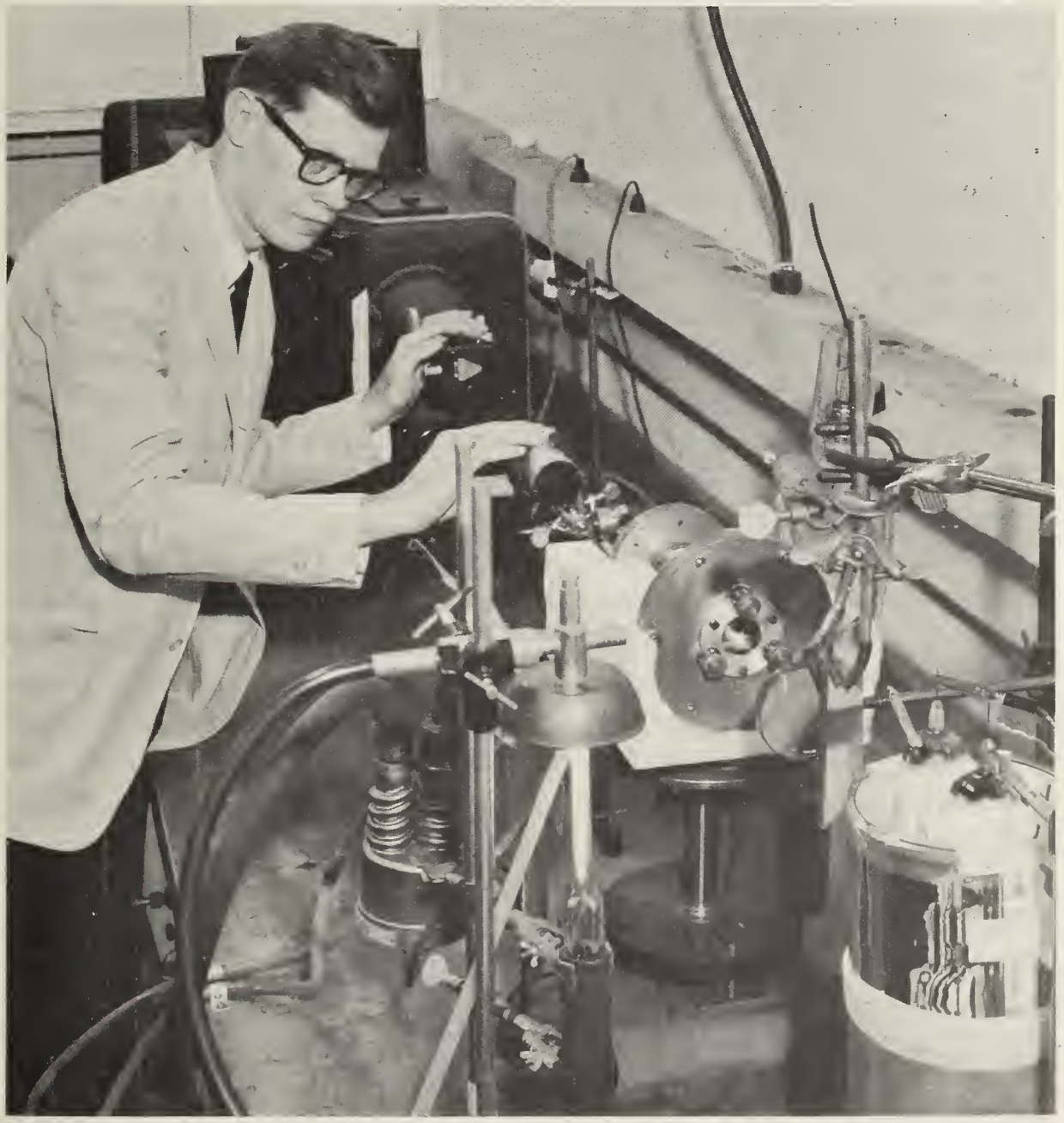
A recalibration of the Bureau's carbon-14 standards formed the basis for a new determination of the half-life of carbon-14. Improvements were made in the accuracy with which the Bureau calibrates instruments used as laboratory standards for gamma-ray measurements by hospitals, industry, and

government. A number of intercomparisons of radioactivity standards were carried out with North and South American, European, and African standardizing laboratories.

To provide a basic reference for humidity measurments, a gravimetric hygrometer was completed. Designed to permit direct weighing of the water contained in known gas volumes, this instrument should make it possible to attain needed improvement in measuring humidity, particularly at temperatures below the freezing point, as in atmospheric studies.

During the past decade vibration measurements have come to play an important part in the development of ships, aircraft, and space vehicles. To provide greater accuracy in these measurements, an improved standard was developed for calibrating vibration pickups.

Precise interferometric measurements on nine lines of the helium spectrum led to an independent confirmation of the Rydberg constant, which since



Equipment used in the redetermination of the Rydberg constant. As a result of this work, it is now the most accurately known atomic constant. The work was done as part of a program of obtaining more accurate values for important physical constants (pages 3, 29).

1952 has been based on the work of a single set of observers. The Rydberg constant relates the energy levels of atoms, and enters into the frequency or wave number formulas for all atomic spectra. The Bureau measurements reevaluated data used in an early determination of the Rydberg constant, bringing this earlier calculation into agreement with the presently accepted value.

Other work on standards and measurement covered a variety of fields. For example, an improved method was worked out for the precise measurement of shock-wave properties; apparatus was devised for special measurements of the heat conductivity of explosives and solid propellants; a precision phase shifter was completed for high-frequency attenuation measurements; a high-resolution infrared spectrometer was designed and constructed; and a technique was developed for measuring ball bearings for high-speed gyroscopes to an accuracy of about five-millionths of an inch.

Properties of Matter and Materials. Much of the work on materials was directed toward the accumulation of basic data on their general properties, constants, structure, and behavior at very high temperatures. For development of heat-resistant materials, extensive studies were made of the solid state reactions that occur in alloys of chromium, iron, nickel, and molybdenum. Under sponsorship of the Wright Air Development Center, a fundamental investigation was conducted to clarify the mechanisms of the processes used to apply refractory oxide coatings to missiles and rockets. Another program was undertaken for WADC to obtain high-temperature thermodynamic data on the light elements—lithium, magnesium, aluminum, and beryllium—and their compounds. These data are essential for the prediction of chemical reactions at high temperatures and for a systematic evaluation of prospective high-energy solid propellants for rockets.

For use in high-temperature strain gages, a cement composition was developed which has higher electrical resistivity in the range 425° to 1,000° C than any similar material now available. As part of a program to determine the strength of ceramics at elevated temperatures, the elastic constants of aluminum oxide single crystals (sapphire) were determined to high precision. Materials such as aluminum oxide are of interest not only for high-temperature structural use but also as electrical insulators.

Other projects, important to the efficient utilization of liquefied-gas rocket fuels, dealt with the properties of materials at extremely low temperatures, not far above absolute zero. For insulation in this temperature range, evacuated laminates were developed that give tenfold improvement over the best evacuated powders. The laminates consist of alternate layers of aluminum foil and thin glass-fiber paper. Their application in engineering design should permit much greater simplicity and compactness in the large vessels now used to hold liquid hydrogen or liquid helium.

A convenient analytical method was developed for determining as little as one-billionth of a milligram of tritium—the radioactive isotope of hydrogen—in water-soluble, nonvolatile materials. This method makes the quanti-

tative determination of tritium relatively easy and thus removes the most important obstacle to widespread use of tritium as a research tool in organic and biological chemistry, where its possible applications are virtually unlimited.

The separation and determination of small amounts of phosphate, silicate, and arsenate when they occur together in solution has long been a difficult problem. During the year, a rapid, accurate method was developed for quantitatively separating and determining these ions. The method should prove useful in controlling the quality of chemicals, metals, glasses, and water which contain these salts as impurities.

Fundamental studies of photochemical reactions involved in air pollution were conducted with the partial support of the Department of Health, Education, and Welfare. These studies were part of a larger program which seeks knowledge of elementary chemical reactions and the mechanisms of energy transfer. Extensive investigation of the primary dissociative processes for several compounds, showed that these compounds dissociate by molecular rearrangement and that free radicals are formed in the primary processes.

In an investigation of the behavior of solids under pressure, spectroscopic evidence was found which shows changes in molecular structures under pressures of 30,000 atmospheres. Information was obtained on the reaction mechanisms involved in the degradation of synthetic resins and collagen—the parent substance of leather—when exposed to high temperatures or to nuclear radiation. In studies of semiconducting materials, the electrical conductivity, Hall effect, and thermoelectric power of titanium dioxide were measured over a wide temperature range.

Radio Propagation. The NBS Central Radio Propagation Laboratory conducted a broad range of research projects on the fundamental nature of radio waves, the basic theories of radio-wave propagation, and the characteristics of radio energy under widely varying conditions. In the course of this work, a promising method was developed for studying the physics of the upper reaches of the ionosphere. Utilizing special radar scatter techniques, the method permits studies of ionization at levels of the atmosphere well above the reflecting layers reached by conventional sounding techniques and into the region now associated with satellite exploration.

Under the sponsorship of the Air Force Cambridge Research Center, CRPL completed a 3-year investigation to determine the feasibility of a long-distance radio communication system based on reflections from meteor trails. During the investigation, an experimental two-way communication system was developed that can transmit messages at speeds up to 4,800 words a minute—80 times the present speed of transmission by teletype. Results of the study indicate that intermittent meteor burst communication can compete effectively with other long-distance systems, and that it is relatively free from ionospheric disturbances.

Further improvements were made in methods for predicting the tropospheric bending of radio waves in terms of the radio-refractive index at the

Two of the three 60-ft diameter parabaloidal antennas installed to make improved measurements of radio wave refraction in the earth's atmosphere (pages 5, 115).

surface of the earth; these methods are expected to aid in improving radar direction finding and radio missile or satellite guidance systems. Climatological maps of the surface radio-refractive index were prepared for the United States and for the World. A method was developed for determining the transmission loss for very closely spaced antennas. To aid in the solution of practical communication problems, a measurement technique was devised for investigating the attenuation of radio waves in passing through various building materials.

Applied Mathematics and Data Processing. A Research Information Center and Advisory Service on Information Processing, to be operated jointly by the National Bureau of Standards and the National Science Foundation, was established at the Bureau. The new service is designed to bring together research and development data on methods and equipment for the automatic processing of scientific information.

Work continued on the Pilot Data Processor, a multipurpose computer network for the experimental investigation of Government data processing problems. During the year the logical plans for the entire PILOT system were transcribed into a form suitable for processing on a high-speed computer to convert them into wiring tables describing the point-to-point electronic interconnections. Considerable progress was made in engineering design and actual construction of this machine.

A study was made of the logical problems arising when several high-speed electronic computers are connected together to work on a common large-scale task. Computer routines were worked out for rapidly and precisely determining color differences between samples. In a study conducted for the Veterans' Administration, a method was developed for using a high-speed electronic computer to analyze data on human heartbeats.

Experiments in machine translation, which the Bureau has been conducting for the Army Office of Ordnance Research, indicated a promising avenue of approach to practical production of English text from Russian technical literature. A translation scheme was developed and feasibility studies carried out on an electronic computer.

Research in mathematical physics included an analysis of the important problem of the mechanics of turbulent diffusion by the techniques of statistical mechanics. A statistical approach was also applied in studying the kinetic equation for a plasma. Other work included a determination of the fluctuations in the annual flows and runoffs of rivers, investigations of the behavior of the solutions of the first-order nonlinear Poincaré equation and the second-order nonlinear Rayleigh equation, and a study of the thermodynamics and hydrodynamics of two-phase flows.

Calibration, Testing, and Standard Samples. The current rapid development of the Nation's technology was reflected in a greatly increased demand for the Bureau's calibration services, and for new or more accurate measurement standards in the more rapidly advancing fields such as electronics, high temperature, and high pressure. To aid in the calibration work, extensive calibration programs are being established in the military agencies and in many industries and private standards organizations. To an increasing extent, the Bureau was called upon for assistance to the other standards laboratories that have been set up.

The Bureau worked closely with the Department of Defense and its contractors in order to keep informed of new measurement problems and calibration needs. In particular, a joint NBS-U.S. Air Force Working Group on precision measurements and calibrations was formed and began studies of present and anticipated calibration requirements. Similar working relationships are being established with the other military services to determine their present and future requirements.

The standardization needs of American industry were emphasized by the results of questionnaires which various professional groups (Aerospace Indutries Association, National Security Industries Association, and Electronic Industries Association) submitted to their affiliated industries. The Aerospace Industries Association surveyed about 70 large industries in its field and found greatly increased measurement needs in a number of critical areas such as microwave, temperature, vibration, and shock measurements. This survey brought out the need for more basic research on measurement problems and increased dissemination of calibration procedures on an industry-wide basis.

Within the limits of its facilities, the Bureau concentrated on those calibra-

tion activities that were most urgently needed by the country. Efforts were made to develop improved standards and calibration techniques in critical areas and to provide for calibration of master standards in other laboratories in terms of the national standards. Plans were made for a million-pound deadweight testing facility to calibrate devices for measuring large forces such as rocket thrusts. A new high-energy accelerator was also being designed to provide needed measurement services in high-energy radiation.

Progress was made in adapting automatic methods to routine calibration work in several areas. For example, automatic equipment was developed to aid in the calibration of multibillion-ohm resistors, and electronic means were devised for comparing line standards of length interferometrically.

The nature and scope of the Bureau's activity in calibration, testing, and standard samples are shown for fiscal year 1959 in tables 1, 2, and 3, respectively. As a result of the growing interest in standards by science and industry, the number of items in each of the three categories was significantly greater than in 1958. The total number of calibrations and tests was 146,217, representing an increase of 12,056 over the previous year. In addition, 63,435 individual samples of certified standard materials were issued, as compared with 55,523 for fiscal 1958. Thirty new standard materials were developed during the year, bringing the total number of standard materials now available to 614.

Fiscal year 1959 was the first full year of operation of the Bureau's new Electronic Calibration Center. Although instrumentation for the center was far from complete, it was able to carry an important part of the calibration load, performing more than 8,500 individual calibrations in the radio-electronics field during the year. This figure was about 17 times the number of such calibrations for the previous year.

More detailed descriptions of work in calibration, testing, and development of standard samples are given in section 2 within the subsections devoted to the corresponding research areas.

Cooperative Activities. The Bureau cooperates extensively with Federal, State, and local governments; with national professional societies and standardizing bodies; and with many international groups. In this way the results of Bureau research are brought to bear on many current problems of science and industry, particularly those relating to measurement standards, building and safety codes, engineering and purchase specifications, and test methods.

Cooperation with other Federal agencies ranges from the supplying of technical information upon request to long-range projects undertaken through various scientific and technical committees. An important example of interagency cooperation is the development of Government specifications and test methods. During the year at the request of the General Services Administration, the Bureau accepted responsibility for developing and maintaining 5 additional Federal Specifications, making a total of 210 for which it now has this responsibility. The Bureau also reviewed approximately 355 proposed specifications both for GSA and for other agencies to determine

TABLE 1. *Summary of calibration services*

Areas of Bureau activities	Representative items	Public		Government		Totals	
		Number of items	Value	Number of items	Value	Number of items	Value
Electricity and Electronics	Electrical instruments, standard cells, resistance, reactance and capacitance standards, d-c to 30 kc.	7,472	$117,510.50	2,758	$39,468.50	10,230	$156,979.00
Optics and Metrology	Light and color standards, photographic lenses, gage blocks and other length standards, refractive index standards, sieves.	16,719	81,849.20	2,068	32,104.85	18,787	113,954.05
Heat	Resistance and liquid-in-glass thermometers, thermocouples, pyrometers.	7,304	87,256.18	2,437	42,573.00	9,741	129,829.18
Atomic and Radiation Physics	Neutron sources and instruments, X-ray and gamma-ray protective materials and instruments, gamma-ray sources; alpha-ray sources, radioactive materials.	616	13,980.50	526	19,155.78	1,142	33,136.28
Mechanics	Acoustic instruments, proving rings, load cells, dynamometers, pressure standards, mass standards, track scales, capacity standards, water current meters.	32,614	180,696.99	4,024	73,799.40	36,638	254,496.39
Building Technology	Thermal conductivity, insulating materials	16	2,485.00	16	1,928.00	32	4,413.00
Radio Standards	Electrical and electronic instruments and standards in radio, ultra-high frequency and microwave ranges.	660	26,069.51	7,364	551,287.88	8,594	577,357.39
Totals		65,401	509,847.88	19,193	760,317.41	85,164	1,270,165.29

TABLE 2. *Summary of testing services*

Areas of activities	Description of samples	Public		Government		Totals	
		Number of samples	Value	Number of samples	Value	Number of samples	Value
Electricity and Electronics	Dry cells, hearing aid batteries, storage batteries			1,284	$11,951.00	1,284	$11,951.00
Optics and Metrology	Lamps			5,655	55,700.00	5,655	55,700.00
Atomic and Radiation Physics	Radioactive materials			389	23,869.00	389	23,869.00
Chemistry	Paints and other surface coatings, detergents, reagent chemicals.	293	$20,940.50	418	19,218.00	711	40,158.50
Mechanics	Mechanical devices, furniture			1,223	10,956.00	1,223	10,956.00
Organic and Fibrous Materials	Paper, textiles, rubber, leather, and plastic products	450	26,858.00	6,065	87,902.25	6,515	114,760.25
Metallurgy	Metals and alloys			37	13,565.00	37	13,565.00
Mineral Products	Cement, concrete and concreting materials, ceramic products.	336	12,034.96	44,148	1,043,342.03	44,484	1,055,376.99
Building Technology	Building materials, elevators, air filters, fire extinguishers, heating and air conditioning equipment.	6	16,900.00	649	34,957.45	655	51,857.45
Totals		1,085	76,733.46	59,868	1,301,460.73	61,053	1,378,194.19

TABLE 3. *Standard samples issued*

Areas of activities	Description of samples	Public		Government			
				Federal		State	
		Number of samples	Value	Number of samples	Value	Number of samples	Value
Optics and Metrology	Resolution test charts	5,814	$1,162.80	385	$77.00	5	$1.00
	Photometric standards	223	5,365.00	11	396.00		
	Spectrophotometric standards	56	2,836.00	4	276.00		
	Color temperature standards	40	1,553.00	1	28.00		
	Reflectance standards	181	2,387.00	59	715.00		
	Opacity standards	59	1,391.00	7	151.00		
	Signal glass limit standards	162	7,794.00	4	210.00		
	Gloss standards	117	1,613.00	16	195.00		
	Oil standards	20	340.00				
	Haze standards	40	466.00				
Heat	Viscosity oils	815	13,610.50	53	871.50	27	336.50
Atomic and Radiation Physics	Radiation lamps	17	1,343.00	4	316.00	3	237.00
	Radioactive standards	297	6,210.00	123	2,701.00	72	1,530.00
Chemistry	Paint pigments	48	144.00	8	24.00	7	21.00
	Sucrose and dextrose	275	1,031.75	17	63.75	45	168.75
	Pure substances, metals, alloys and ores	20,856	90,826.50	1,158	4,977.00	343	1,353.75
	Uranium isotopic standards	376	5,408.50	36	721.20		
	Spectrographic standards	4,544	33,516.00	617	4,848.00	86	752.00
	Pure hydrocarbons	445	12,984.00	85	2,193.00	103	2,973.00
	Labeled carbohydrates	11,235	12,277.50	4,225	5,215.00		
	Methane fuel gas samples	67	4,990.00	4	160.00		
	Thickness samples for electroplated coatings	1,789	18,058.50				
	Standard benzoic acid thermometric cells	4	815.00	1	220.00		
Organic and Fibrous Materials	Standard fading samples	494	4,271.00	11	102.00	4	58.00
	Rubber and compounding ingredients	4,926	23,737.45	22	118.95		
	Phosphor reference samples	342	1,026.00	32	96.00	14	42.00
Metallurgy	Gases-in-metals samples	230	2,300.00	38	380.00	12	120.00
Mineral Products	Cement	2,150	5,375.00	41	102.50	79	197.50
Building Technology	Limestone slabs	31	663.00	15	375.00	5	61.00
Totals		55,653	263,495.50	6,977	25,532.90	805	7,851.50

their suitability for use by the Federal Government.

Cooperation with State and municipal governments is principally in the field of weights and measures. Although the Bureau itself does not have regulatory powers, it contributes to the local bodies the means and methods whereby measurements in commerce may be made in a uniform manner, consistent with the national standards. A major medium of cooperation is the National Conference on Weights and Measures. Thirty-nine States, Puerto Rico, and the District of Columbia were officially represented at the 44th annual meeting of this Conference, held in Washington, D.C., June 8–12, under NBS sponsorship.

On March 3 standards of the fundamental units involved in commercial exchange were presented to the new State of Alaska in a special program held at the Bureau. Work was under way during the year to develop new physical standards for the states that would be more accurate, constant, and durable.

Through the participation of Bureau staff members in the work of professional societies and national standardizing bodies, the Bureau plays an active role in the development of test methods and criteria, in the application of scientific discoveries, and in fundamental research programs of a national nature. During the past year Bureau staff members held about 1,592 committee memberships in more than 186 national groups such as the American Society for Testing Materials, the American Standards Association, American Society of Mechanical Engineers, American Chemical Society, Institute of Radio Engineers, and Instrument Society of America. In many of these groups NBS staff members work with industry to improve engineering standards, purchase specifications, and building and safety codes.

Two other important types of Bureau-industry cooperation are the Research Associate Plan and the donor program. Under the Research Associate Plan, technical, industrial, and commercial organizations can support work at the Bureau on projects that are of special interest to them, yet are of sufficient general interest to justify use of government facilities. These projects must also be important from the standpoint of the Nation's sum total of technological knowledge. The work is done by research associates who are paid by the sponsor but otherwise function as members of the Bureau staff. At the present time 12 groups are supporting research associates at the Bureau (appendix 3.7).

The donor program was authorized in 1950 by Public Law 619 under which the Bureau may accept funds for the purpose of furthering its work. This arrangement permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public. During the past year, 18 projects were supported by gifts from 32 organizations (p. 147).

On an international basis, the Bureau represents the interests of the Government and American science in matters dealing with the establishment and maintenance of standards and establishment of values for scientific constants. Most of this work is done through participation in a large number of inter-

national groups such as the International Union of Pure and Applied Physics, International Scientific Radio Union, International Commission on Illumination, and International Organization for Standardization. Approximately 100 staff members attended meetings of international societies during the fiscal year.

In October 1958 the Director of the National Bureau of Standards attended a meeting of the International Committee on Weights and Measures at Sèvres, France. This Committee is an executive body of the General Conference on Weights and Measures, which normally convenes only at 6-year intervals. The Committee took an important and nearly final step toward achieving an atomic definition for the meter, recommending to the General Conference (which meets again in 1960) that the meter be defined in terms of the orange line of krypton-86. The Committee also recommended a number of revisions in the Treaty of the Meter, and that an international program be established on standards for measuring ionizing radiations.

To secure identical values for the yard and pound in precise measurements, an international yard and an international pound were adopted by agreement between the directors of the national standards laboratories of six English-speaking nations: Canada, New Zealand, United States, United Kingdom, South Africa, and Australia. According to the agreement, the international yard equals 0.9144 meter and the international pound equals 0.453 592 37 kilogram. On July 1, 1959, the Bureau began making all calibrations of length and mass (except those for the U.S. Coast and Geodetic Survey and those expressed in metric units) in terms of the international yard and the international pound.

Another phase of international cooperation involves a program whereby scientists or diplomatic repres ntatives from other countries are accepted at the Bureau as guest workers or visitors. Approximately 900 foreign scientists and technicians, representing 50 countries, visited the Bureau during the year. Twenty-eight of these visitors were specialists who came as guest workers to spend from 1 to 12 months in cooperative research in such fields as radio propagation, free radicals, mathematics, and dental materials. Eleven were trainees who were being prepared for leadership in the national laboratories of their own countries.

Administrative Activities

Bureau programs are financed by four sources of funds: Direct appropriations from the Congress, transferred funds from other Federal agencies, fees paid by private organizations for calibration services and standard samples, and gifts from private sources.

During 1959, the total funds obligated, including construction and facilities, were $34,839,000. Of this total, $12,379,000 came from the direct appropriation for the Bureau's research and technical services and $2,709,000 from the direct appropriation for facilities and for the design of new laboratories. The remaining $19,751,000 came from other agencies and private sources (see p. 138).

At the close of the year the Bureau's total staff was 3,425, of which 42 percent were in the professional categories. In the professional group were over 500 physicists, 300 chemists, 250 engineers, and 100 mathematicians. Of the total staff, about 1,000 were stationed at the Boulder Laboratories and its associated field stations, 43 were in other field installations, and the balance were in Washington, D.C.

A new research division was established in the Central Radio Propagation Laboratory. The new Radio Communication and Systems Division will expand the research and development services provided for agencies which use radio communications. In particular, it will deal with research in radio communication and navigation techniques, and the application of radio propagation studies in the improvement of radio systems. The Division will also be responsible for the coordination within the Boulder Laboratories of the radio systems problems of other agencies, and for direct liaison with these agencies in providing the services necessary.

In order to achieve greater coordination in the work of many projects of closely related interest and in order to promote rapid progress in specially designated research areas, the Bureau will appoint coordinators of interdivisional research programs who will have the following technical and advisory responsibilities: (1) Definition of the area of research, (2) identification of staff to undertake the program, (3) increasing interdivision cooperation, and (4) reviewing and reporting on the program. The first coordinator of such a program has been appointed in the field of plasma and astrophysics.

During the year considerable progress was made in the design planning of the new laboratories to be located at Gaithersburg, Md. By the end of the year many of the Gaithersburg buildings were in the final stages of architectural drawing. Plans were substantially completed for the radiation physics laboratory, including the new linear accelerator, and the engineering mechanics laboratory, including the new million-pound deadweight force measurement machine.

Dr. Robert D. Huntoon, Associate Director for Physics, was appointed to the new position of Deputy Director of the Bureau. He serves as the Director's alternate in representing the Bureau and exercises fully delegated authority in the direction, coordination, and review of Bureau programs and administration.

The passage of the Government Employees Training Act of 1958 provided the Bureau with the opportunity to support additional training and education for staff members to aid in meeting the changing and expanding technical requirements of Bureau responsibilities (see appendix 3.6).

Programs Planned

At the close of the fiscal year, plans had been made for greatly intensified effort in three critical areas: (1) High-purity materials, (2) plasma- and astrophysics, and (3) very high pressure.

As science and technology move into unknown environments and new applications of devices, new and better materials are needed to meet unusual conditions. To enable other laboratories to satisfy these requirements without costly trial-and-error procedures, the Bureau must develop and publish more data on the fundamental properties of materials. An important aspect of this work on fundamental properties is the devising of techniques for achieving extremely high purity in materials and criteria for determining purity. Recognizing the need for a national program on high-purity materials, the Bureau plans to initiate a greatly expanded program in this field during the coming year.

Many of the newer fields of technology—such as astronautics, ultrasonic aerodynamics, thermonuclear power, and ionospheric communications—deal with a medium whose characteristics are very poorly understood: an ionized gas, often at very high temperature, whose particles are continuously interacting. The nature and behavior of such a gas, known as a plasma, constitutes a new and challenging field of physics which includes astrophysics, fluid mechanics, and other disciplines. To this general field, the Bureau has been contributing valuable data on atomic spectra, temperature and radiation standards, and ionospheric and solar physics. However, many laboratories working with plasmas have been forced to rely on expensive and inefficient empirical methods because of a lack of precise measurement techniques and basic data on the fundamental properties of this gaseous medium. To help solve this problem, an interdivisional group of scientists was established within the Bureau to plan and coordinate an intensive, unified program in plasma and astrophysics. The program as planned falls naturally into three parts: (1) Atomic properties, (2) gases near equilibrium or idealized conditions, and (3) gases far from thermodynamic equilibrium. Parts (1) and (2) will be carried on largely at the Washington laboratories, part (3) will involve primarily the Boulder Laboratories.

The use of very high pressures offers considerable promise as a means of developing materials to meet severe requirements in military and industrial applications. Although the Bureau has been conducting research on high pressure for some time, there is still a pressing need for a well-defined pressure scale, standard measurement methods, and precise data on properties of materials at various regions on the pressure scale. The Bureau will therefore begin in fiscal 1960 a special program to develop standards, measurement techniques, and data on properties in the very-high-pressure field.

Publications

The results of the Bureau's research programs are conveyed to the scientific and technological community largely by reports and publications. Even when the work is developmental in nature—for example, the development of a specific instrument—the activity will culminate in a report, and it is the report which will often prove of most value to Government, science, and industry.

In the past year, the Bureau's publications program was reevaluated. Effective July 1959, the *Journal of Research of the National Bureau of Standards*, the Bureau's main periodical, will be divided into four separately published sections. Corresponding to subject matter fields, the four sections may be subscribed for individually. At the same time, the scope of the Journal will be broadened to cover the Bureau's scientific program even more completely. The four sections will be: A. Physics and Chemistry, B. Mathematics and Mathematical Physics, C. Engineering and Instrumentation, and D. Radio Propagation.

Two nonperiodicals, *Circulars* and *Building Materials and Structures Reports*, will be discontinued, and the type of material they formerly contained will appear in the expanded *Journal of Research*. Two new nonperiodicals, *Monographs* and *Technical Notes*, will be established. *Monographs* will consist of major contributions to technical literature which are too long for publication in the *Journal*, and the *Technical Notes* will make available communications and reports which are of limited or transient interest.

Among the major nonperiodicals published during the year was NBS Handbook 69, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure*, which set forth the latest recommendations of the National Committee on Radiation Protection and Measurements on this subject. Also appearing was the eighth volume of *Standard X-Ray Diffraction Powder Patterns*, NBS Circular 539. This circular contains data needed for chemical analysis by X-ray diffraction. One of the final issues of the Building Materials and Structures Reports Series was an updated edition of the *Selected Bibliography on Building Construction and Maintenance.*

During the year, the Bureau's reports and publications totaled 1268, exclusive of calibration and test reports and of general administrative documents. Some 541 classified and unclassified reports were issued to other government agencies, while 727 papers and documents were published formally.

Of the formal publications, 85 were published in the *Journal of Research*, and 484 in the journals of professional, engineering, and trade organizations. There were 134 summary articles published in the Bureau's monthly *Technical News Bulletin.* Twenty-four papers were published in the nonperiodical series of publications: 2 in the Applied Mathematics series, 2 in the Handbook series, 14 in the Circular series, 3 in the Building Materials and Structures Reports series, and 3 in the Miscellaneous Publications series.

The other monthly Bureau publication, *Basic Radio Propagation Predictions*, which is published for a 1-month period 3 months in advance, presented radio propagation data needed in determining the best frequencies to use in long-range radio communications.

A list of publications for the fiscal year is given in the appendix, section 3.8 (p. 148).

2. Highlights of the Research Program

The Bureau's technical program is carried out through organizational units called divisions. These are shown in appendix 3.1. A review of selected research and development programs is presented in this section under headings corresponding generally to these organizational units.

2.1. Electricity and Electronics

The Bureau's work in electricity is primarily the development, improvement, and dissemination of the standards of measurement for electrical quantities, and the study of the properties of materials that are important in all applications of electricity and magnetism. The object is to provide electrical standards that are constant over long periods of time, uniform throughout the Nation, and consistent with the fundamental mechanical units.

The electronic activities include the standardization of test methods for electronic components, the study of processes and materials for component fabrication, and the establishment of optimum designs of electronic equipment for maximum life and reliability. Electronic development programs are undertaken to meet the special requirements of the Bureau and, in areas where the Bureau is uniquely qualified, those of other government agencies.

The demand for the calibration services by which the electrical standards are disseminated throughout the Nation continued to increase and was about 25 percent greater than the preceding year. This demand was met without accumulating a serious backlog. In addition, development of standards of capacitance continued. Methods for using these standards, both in calibration of other capacitances and as a basis for the absolute determination of the ohm, were developed. Measurements on instrument transformers were extended to audiofrequencies with greater accuracy than in previous years and have made possible improved calibrations of a-c potential dividers.

Several continuing basic research programs in the Electricity and Electronics Division are concerned with measuring the fundamental electrical properties of materials. These include investigations of dielectric materials, and methods of measuring the characteristics of electronic component parts and such materials as mica.

Automatically Measuring High Resistance. Precisely measuring resistors of extremely high values requires determining the current flowing through the resistor into a capacitor whose value is continually changed. Because the capacitor is adjusted manually, and because the test can be long and tedious, the Bureau developed an automatic device to drive the capacitor at the proper rate.

Computable Standard of Capacitance. Work has continued on a capacitance bridge that makes possible capacitance measurements with a precision of about one part in a million over the range from 1 picofarad to 1 millifarad. The successful design of this experimental bridge led to the

construction of two of essentially the same type for the Bureau's calibration services. To obtain an accuracy comparable with the precision, it has been necessary to design and build a capacitance standard whose value can be computed from its dimensions. Such a capacitor has been constructed and tested. Tests so far seem to show that the computable capacitor can be disassembled and reassembled, with a variation in its capacitance of no more than one part in a million. It is believed that the capacitance is known to a comparable accuracy as its value depends only on the length of two 10-in. gage bars.

Electron Devices Data Service. A revised tabulation of data on receiving tubes has been compiled from the information available on coded punched cards in the files of the Data Service and is being issued as an NBS handbook.

At present there are more than 20,000 individual types of electron devices manufactured by domestic and foreign manufacturers. As few users have access to a complete library of manuals containing the information on these devices, the Bureau's Electron Devices Data Service is making the technical data on such devices readily available to technical personnel. These devices are cataloged mainly according to type number and major electrical characteristics. Considerable data on devices manufactured in Europe and Japan were recently added.

Ceramic Wafer Tubes. A ceramic electron tube readily adaptable to fully mechanized production methods has been developed under sponsorship of the Navy Bureau of Aeronautics. These tubes are compatible with the modularized electronic circuitry developed as part of the Project Tinkertoy program announced in an earlier annual report. Tubes have been produced in a commercial plant in pilot quantity. They are now being incorporated in complete modular circuit packages for a military application where their reliability can be observed in actual use under extreme conditions of shock, vibration, and temperature.

Methods for Testing Servo Motors. Servo motors have become of increasing importance in devices where precise remote control of motions is important. At the request of a committee of the Society of Automotive Engineers, the various test methods in use by several manufacturers were studied experimentally and the necessary precautions to insure concordant measurements by each method were evaluated and reported to the committee. As a result, agreement between the manufacturers within certain desired accuracy limitations is now possible.

Dielectric Properties of Nylon. The electrical properties of poly(hexamethylene adipamide), 66 nylon, a useful dielectric, was studied intensively. The electrical measurements were made on desiccated samples in a special cell designed for use at low temperatures. The dielectric constant and dissipation factor were measured over wide ranges of frequencies and temperatures. The values of dielectric loss factor obtained were lower than any previously reported in the literature. Also, a normally present peak in the loss factor was barely observable in the desiccated nylon samples. Indi-

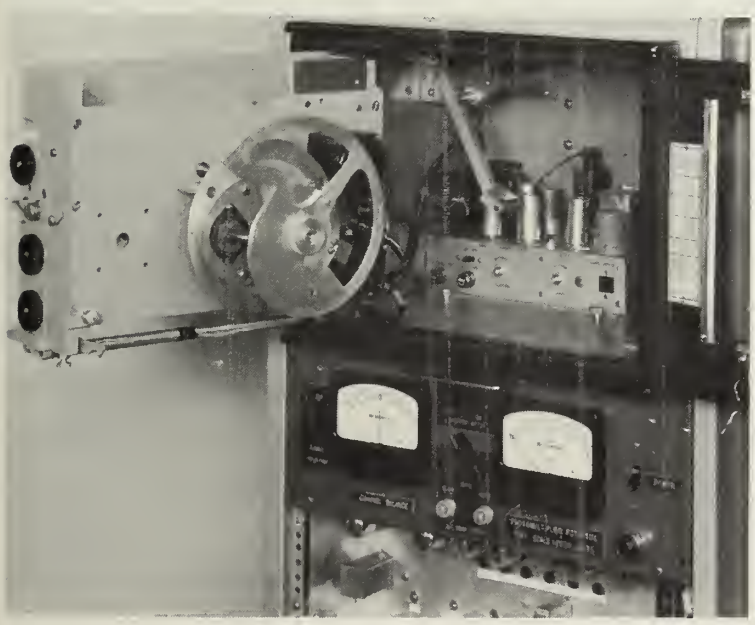
cations are that this loss peak is not a property of the nylon, but of the water remaining in the nylon. Measurements of the dielectric properties show the existence of a relaxation process that is an intrinsic property of the polymer and is characterized by an activation energy about 12 kilocalories per mole.

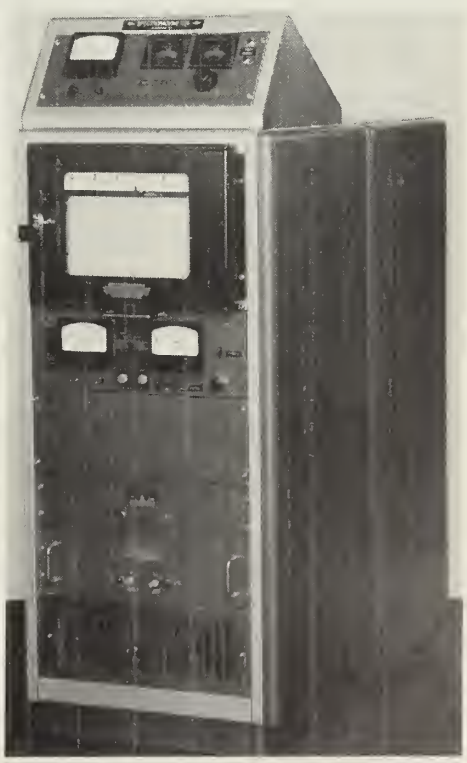
Preferred Circuits. The preferred circuits program, sponsored by the Navy Bureau of Aeronautics, has continued with the development of new circuits. Two supplements to the Preferred Circuits Manual were released by the National Bureau of Standards. The original manual contained only vacuum tube circuits, but in the supplements some transitorized circuits are presented. Future supplements will increasingly emphasize transistor circuits in accordance with present-day trends.

Recording Spectroradiometer. A recording spectroradiometer was developed to measure the ratio of the spectral light intensities of two lamps as a function of light wavelength. By comparing a test lamp with a standard lamp, the machine can automatically plot this ratio over the visible spectrum in a few minutes. The process formerly required several hours when performed manually.

Electronic Metrology. Calibrating length standards is a tedious and exacting task when performed manually and research has been under way to mechanize this process. An electronic technique was developed to sense and record the number of light fringes observed during the motion of an interferometer, and to detect an engraved line marking a length scale. Extension of these developments is expected to lead to a machine for calibrating industrial and scientific line scales automatically.

Galvanic Corrosion of Metallic Silver. During the course of determining the faraday, the rate of corrosion of silver in certain aqueous solu-





Recording spectroradiometer, developed to measure the ratio of the spectral intensities of two lamps as a function of wavelength. This measurement, which previously required several hours, is now performed automatically in a few minutes over the visible spectrum. *Above:* view of the strip chart mechanism (page 19).

tions was measured. Silver does not undergo thermodynamic chemical reaction with perchloric acid; thermodynamically, it may dissolve in some solutions containing oxygen or go into solution as a result of galvanic corrosion arising from local anodic and cathodic areas on the silver surface. The rates of these reactions are very low, and the corrosion current density is extremely minute. An additional finding was that the corrosion current density of silver in distilled water appeared to be nil.

Evaluating Storage Batteries. In recent years the use of industrial trucks and tractors propelled by electric batteries has shown marked increase in material handling in government warehouses. The Bureau has developed standard test procedures for evaluating such motive power batteries for the Navy Bureau of Supplies and Accounts. Two general procedures were used: A simulated service test and a life cycle test. Methods were also developed for testing such batteries under various rates of discharge, under vibration, and under variations in temperature.

A special purpose simulator was designed to incorporate appropriate procedures for evaluating storage batteries for use in helicopters. The simulator is a self-contained unit that operates and records data with no one in attendance. It consists of a programing device, discharge circuit, charging circuits, a motor generator set, and instrument panels.

Dry Cell Specifications. A revision of specifications for dry cells and batteries has been completed for the American Standards Association and will be issued as an NBS handbook. New material in this specification includes data on cells and batteries for use with transistors, dimensions in both the metric and English systems, cell designations adapted by the International Electrotechnical Commission, and standard terminal arrangements. The specification also includes performance data on flashlight cells, radio batteries, telephone cells, railroad lantern batteries, hearing-aid cells, alarm system batteries, photoflash cells, C batteries, and A/B battery packs.

International Comparison of Transformer Ratio Measurements. The first international comparison of instrument transformer ratio measurements was made using four multirange transformers belonging to the Physikalisch Technische Bundesanstalt. Test included current ratios from 1/5 to 10,000/5 amperes and voltage ratios from 3,000/100 to 230,000/100 volts. Accurate ratio and phase-angle determinations on such devices have to be used not only for all large power and energy measurements, but also in instrument laboratories, where they furnish an important part of the basis for the precise determination of large alternating currents and voltages. Such transformers of suitable construction provide ratio standards that are known to be stable within a few parts per million. Also participating were the National Research Council Laboratories of Canada; preliminary values of ratios and phase-angles over the entire range of currents and voltages show good agreement among the three national laboratories.

The first international comparison of instrument transformer ratio measurements was made using four multirange transformers belonging to the German Physikalisch Technische Bundesanstalt. Such transformers are used for

The largest of four standard transformers from the Physikalisch Technische Bundesanstalt (the West German national laboratory) which were tested by the Bureau. Ratio and phase-angle measurements were made as part of this first international comparison of standards for alternating current and voltage measurements. The United States, Germany, and Canada participated in this program (page 20).

making accurate ratio and phase-angle determinations for large power and energy measurements, and also in measurement laboratories where they furnish an important part of the basis for the precise determination of large alternating currents and voltages. Preliminary values of the calibrations or ratios and phase-angles over a wide range of currents and voltages show good agreement among the three national laboratories.

2.2. Optics and Metrology

The Bureau's work in optics and metrology is principally concerned with the development of standards for classical optics and for length measurement, and with the establishment of procedures for the precise use of these standards. During the past year good progress was made in developing atomic beam sources for standards of length, using the beams in both emis-

sion and absorption. In another approach, absorption in a magnetic field was employed to realize a wavelength standard of length that will be convenient for most laboratory applications. Research to improve line sharpness by interferometric filters resulted in line widths capable of producing interferometric fringes with a path difference of 2,000 mm. in a Michelson interferometer.

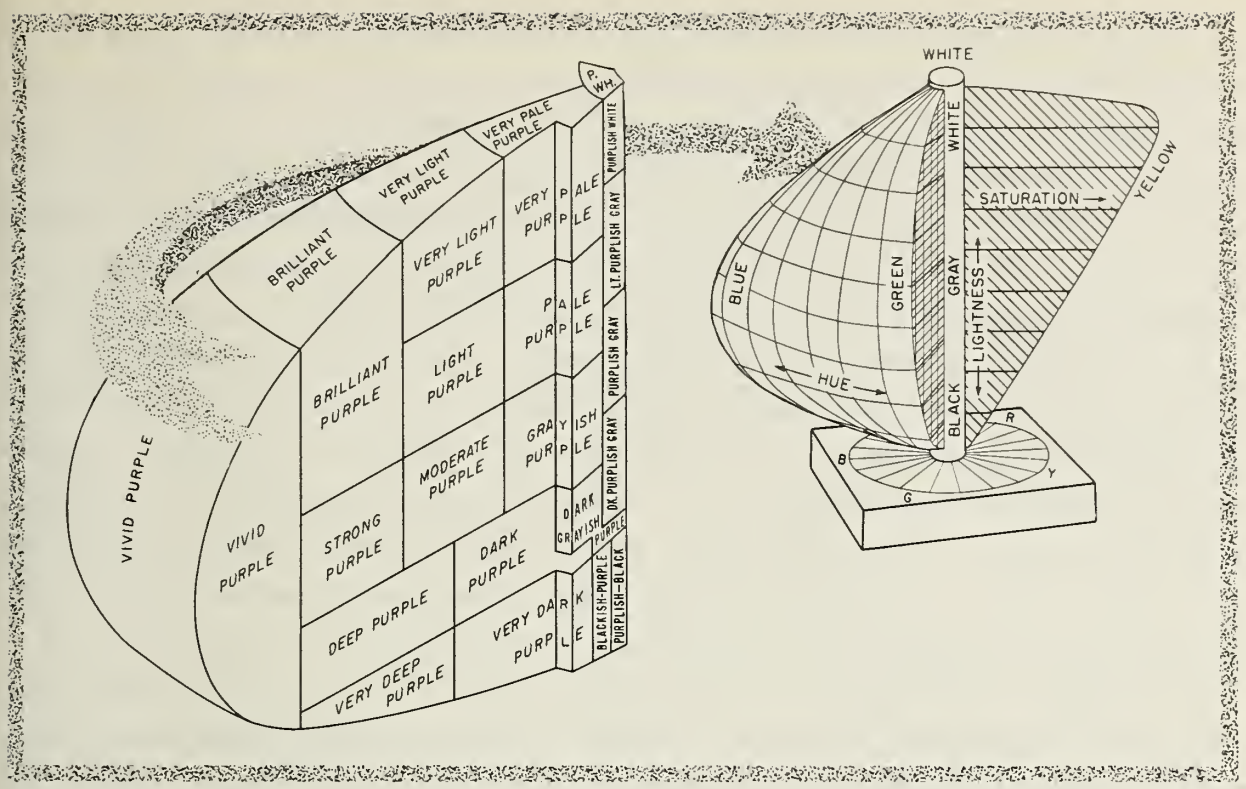
Among new photometric standards made available during the year were lamps with frosted bulbs for measuring the luminous intensity of electric lamps. These standards are more easily oriented for calibrations and show less candlepower variation than the clear-bulb standards previously issued. Three different investigations were facilitated with the aid of the high-speed electronic computer used at the Bureau. They pertained to optical systems design, interferometric calibration of gage blocks, and color difference determinations.

Color Differences by High-Speed Computer. In order that rapid determinations may be made of the color differences in large numbers of samples over a wide range of materials, two formulas were programed for the Bureau's high-speed electronic digital computer. Both programs begin with the fundamental measurement of spectral transmittance or reflectance of a sample color. One, for small difference computations only, is based on the original NBS unit of color difference defined in 1942 in terms of tristimulus values. The other, based directly on the Munsell scales of hue, value, and chroma, may be used for any size of color difference. Color differences between pairs of samples, the tristimulus values of which have been derived spectrophotometrically, are obtained automatically in 5 seconds.

New Color Charts. In a recent color-measurement study conducted in cooperation with the ISCC (Inter-Society Color Council), central notations were determined for the ISCC–NBS color-name blocks. These blocks are defined as segments of a spheroid, each segment encompassing the range of color acceptable under one color name. Fitted together, the segments comprise the psychological color solid that scientists use to represent the gradations in color perceived by the human eye.

The central notations of the blocks were designated in terms of the Munsell tridimensional scales, and paint-on-paper prototypes of the centroid color of each block are being produced. When these prototypes are approved as representative of the blocks from which they derived their color names, they will be reproduced in color charts and published as a supplement to NBS Circular 553, the *ISCC–NBS Method of Designating Colors and a Dictionary of Color Names.*

Lens Aberrations Measured. A visual method was developed for accurately measuring the longitudinal spherical aberration present in lenses. Results obtained are comparable to those derived by the Hartmann photographic method, long considered the near ultimate in this type of work. Prime advantages of the visual process are rapidity of measurement, and the capability for measuring the logitudinal chromatic aberration of lenses with a minimum of effort.



The psychological color solid, showing division into color-name blocks. The centroid colors of these blocks are being produced for use by science and industry (page 22).

Lens Distortion Measurements Refined. An extended investigation of possible errors of adjustment in measuring lens distortion with the nodal slide bench resulted in increasing the accuracy of these measurements by a factor of 10. Values of lens distortion, formerly difficult to determine more closely than to the nearest 20 microns, are now determined to the nearest 2μ. In the course of this study, a visual method of measuring prism effect of lenses was developed.

Lens Calibration Methods Analyzed. At the request of the Air Force, an analysis was undertaken of the principal methods used in calibrating lenses for airplane mapping cameras. Comparisons were made of the photographic method in which a lens testing camera is used, the visual method with the nodal slide bench, and the visual goniometric method. All three techniques assure high precision in photogrammetric lenses when proper care is exercised in taking the measurements. Special caution must be observed to avoid errors resulting from plate curvature, asymmetric use of apertures, prism effect, and instrument misalinement.

Anticollision Lights for Airplanes. As long-range visibility becomes increasingly important to aviation with the supersonic speeds attainable today, the demand has grown for higher and higher intensity in the anticollision lights installed on airplanes. The Bureau, in developing information for the Navy Bureau of Aeronautics on the practical upper limits of luminous intensity for these lights, designed and built a 2,000-watt rotating assembly that produces 12,500 candles of red light. Actual flight tests, however, indicated that the luminous output of the essembly was excessive at times, principally because of atmospheric backscatter. An automatic haze-actuated device was therefore designed to lower intensity when backscatter is objectionable and to raise it as the atmosphere clears.

Visual Landing Aids Devised. New lighting and marking systems were designed for landing areas on land, on sea, and on aircraft carriers, for the Navy Bureau of Aeronautics. One device, known as the approach-beacon system, is a simple, low-cost method of providing visual guidance for circling and radio-range approaches to airfields during marginal weather conditions. It consists of two or more approach beacons located on the extended runway centerline. Installed on each beacon is an array of continuously burning incandescent lights which rotate about a vertical axis to give the appearance of a rapidly flashing light. Another system consists of miniature beacons placed at the corners of a runway or channel, which serve to identify the landing area. A third system fills a need for circling guidance lights. Although present runway lights provide ample guidance to a pilot when he is alined with the runway, this system is designed to aid him while circling the field preparatory to landing.

Photometric Equipment Improved. The basic unit of photometry—the unit of luminous intensity—is defined in terms of the luminance of an ideal radiator (blackbody) immersed in freezing platinum. Although actual radiators depart from the ideal, fairly consistent results in the measurements of photometric units are usually obtained between the various international standardizing laboratories. However, recent investigations at NBS indicate that this consistency resulted from the use by these laboratories of almost identical blackbodies. In studying the effect of deviation from ideal blackbody conditions in the calibration equipment at the Bureau, three correction factors were found necessary: One for the size of the opening at the top of the sight tube which encloses the blackbody; the second, for temperature drop in the walls of the sight tube; and, the third, for that part of the tube not immersed in platinum. When the corrections were made, a significant improvement in consistency over previous measurements was obtained, with results agreeing to well within 0.1 percent.

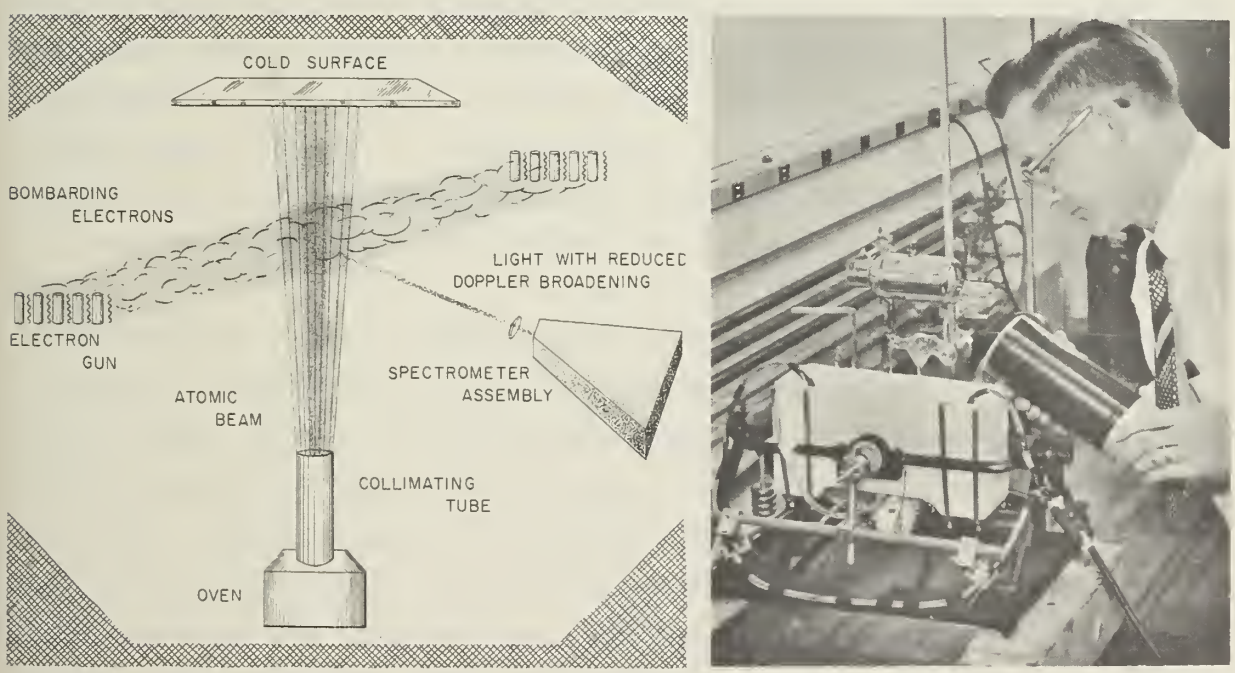
Bearing Ball and Cylinder Measurements Improved. Increased accuracy in measuring steel balls for bearings of the type used in the high-speed gyros of guided missiles was achieved. High-quality steel balls were measured with the repeatability of 2 millionths of an inch, representing an accuracy in the measurement of about 5 millionths of an inch. The balls were placed between steel plates and measured under varying loads by optical interference and corrections were applied for indentation of the plates. Similar measurements were made on cylinders for piston-type pressure gages. Check measurements with the National Physical Laboratory in Great Britain show agreement to 5 millionths of an inch, confirming the accuracy attained by both laboratories.

Interference Fringe Path Extended. An interferometer may be used as a monochromator to transmit a range of wavelengths much less than that corresponding to the original width of the spectral line producing the radiation. This is particularly desirable for length measurement because it increases the distance over which interference may be obtained. For this pur-

pose the use of a Fabry-Perot interferometer with spherical plates is advantageous because it transmits more radiation than one with plane plates. During the past year a spherical interferometer was constructed with which interference fringes were obtained and photographed using a Michelson interferometer with a mirror separation of one meter. The original source of the light was the green line of mercury–198.

Research on Improved Lightwave Length Standards. In investigating methods of producing an improved wavelength standard of length, the Bureau has had success in two promising approaches. One is the atomic beam, which can be used as either an emission or an absorption source, and the other is the Zeeman absorption filter. By producing extremely narrow spectral lines, both of these approaches can increase precision far beyond that presently required by research and technology.

The precision possible with previously developed lightwave standards is limited by Doppler broadening of spectral lines, an effect due to the random motion of emitting atoms toward and away from the observer. Atomic-beam techniques decrease this effect by selecting atoms traveling at right angles to the line of sight. The atomic beam has proved satisfactory in both emission and absorption devices for producing very narrow spectral lines. In both cases the half-width of a line is 0.002 cm^{-1}, one-sixth of the width of the proposed international standard. The action of the Zeeman filter depends on the splitting of spectral lines in a magnetic field. The absorption characteristics of this cell act as a filter, and radiation is passed only by the



Atomic beam principle (left) used by the Bureau to produce narrow emission lines in research on improved wavelength standards of lengths. A collimated beam of mercury atoms emerging from the oven (below white box in photo) is bombarded by electrons. The atoms thus excited emit light which is then viewed at right angles to the motion of the atoms in order to reduce Doppler broadening (page 25).

region where absorption does not occur. With this apparatus a mercury line 0.006 cm^{-1} wide was obtained.

Lens Design by High-Speed Computer. To assist in the design of optical lenses requiring aspheric surfaces, a ray-tracing program for the Bureau's high-speed electronic computer was modified to include a subroutine for tracing rays through an aspheric surface. Another new routine in geometrical optics permits the automatic calculation of the center and diameter of a circle containing 30 percent of the total number of points in a spot diagram. This program may also be used to provide image heights from which the distortion of an aerial camera lens can be calculated at the estimated plane of best focus for a number of aperture openings. The method followed in predicting distortion appears to be superior to the customary procedure in which the height of the principal ray is compared with the ideal image height.

A preliminary program for SEAC (the Bureau's electronic automatic computer), in which spot diagrams are produced and focused on the face of an oscilloscope, was successfully run. A permanent program compatible with the tape output of a commercial computer is being prepared to speed up lens design. It is designed to eliminate the use of a plotting machine, and also the need for estimating the plane of best focus prior to calculating spot diagrams. In addition, the use of a direct photographic process enables superimposed points to be distinguished from a single point, thus giving a much more accurate representation of the distribution of energy in the image than can be obtained at present.

High-Precision Gage Blocks. As improved gage block materials become available (see p. 75), measurement techniques are being refined for measuring the stability of these blocks. During the past year, more than 70 samples submitted by the metallurgy laboratory for testing were measured at regular 1-week, 4-week, and 6-week intervals. Work in this area included periodic absolute interferometric measurments of a master control block, interferometric comparison of selected sample blocks with the master block, and mechanical measurement of the thermal coefficient of expansion and length changes of all stability standards.

Advances in Refractometry. The refractive index of a sample of arsenic trisulfide glass was determined at different temperatures for selected wavelengths in the spectral regions of the ultraviolet, visible, and infrared. After thermal coefficients of index were derived at each wavelength, a Sellmeier-type dispersion equation was fitted to the averaged data, and comparisons were made with the indices of refraction in the visible region that had been obtained for two other samples. A study was also made to obtain preliminary refractive index and dispersion data on a synthetic barium fluoride crystal from 0.25 micron in the ultraviolet to 11 microns in the infrared. These data are valuable to designers of optical systems, spectroscopists, solid state physicists, and in the military application of infrared technology.

In work for the Navy Bureau of Ordnance, lightweight optical glasses were developed at NBS with high refractive indices and high dispersion. These glasses are especially suitable for military applications where weight is of prime importance.

Chemistry of Photographic Fixation. A better understanding of the chemistry of photographic fixation and the factors affecting the permanence of photographic records was obtained from a study of the silver sulfide in photographic images. It was found that some of the silver in a developed photographic image is converted to silver sulfide during the fixing process. A quantitative procedure was developed for reducing silver sulfide in an image to silver so that the sulfide can be measured easily in terms of the optical density of the silver deposit.

New Candlepower Standards. The Bureau recently made available new photometric standards for measuring the candlepower, or luminous intensity, of electric lamps. They consist of 100-, 300-, and 500-watt lamps with inside-frosted bulbs, monoplane filaments, and medium-bipost bases. These lamps are easily oriented on the photometric bar by means of the bi-post bases, require no diaphragm when in use, follow closely the inverse square law, and are superior in the amount of candlepower variation they show with change in orientation to the clear-bulb lamp standards previously issued.

Records Reduction. To assist the Veterans' Administration in reducing the volume of medical records, a study was made of the factors required to design microcopying systems for such records. The significant graphic features of electrocardiograms, charts, and written matter were measured. Based on these measurements, designs were specified to provide a photographic system capable of the greatest reduction in size which at the same time retained the essential informational content of the original records.

Interferometer for Large Surfaces. An instrument was developed to facilitate the testing of precision flat surfaces such as aircraft fixtures, machine ways, and layout plates. The device is a simple, sensitive interferometer which examines surfaces by producing a set of interference fringes, which is, in effect, a contour map of the test area. Areas of any length can be tested by merely adjusting the angle of incidence of the light on the surface. The width of the area examined at each setting is always equal to the linear aperture of the instrument. This development, by insuring the flatness of surfaces on which precision machine parts are compared, is expected to aid materially in the control of dimensional tolerances.

Filter and Brightness Standards. Among the numerous standards issued during the past year were red filter standards and brightness standards for calibrating the instruments used throughout the aviation industry in the measurement of military airplane instrument lighting panels. With the aid of these, standards instrument panels can be made bright enough to be adequately legible, but low enough in emission of shortwave visible energy not to impair the dark adaption of the pilot.

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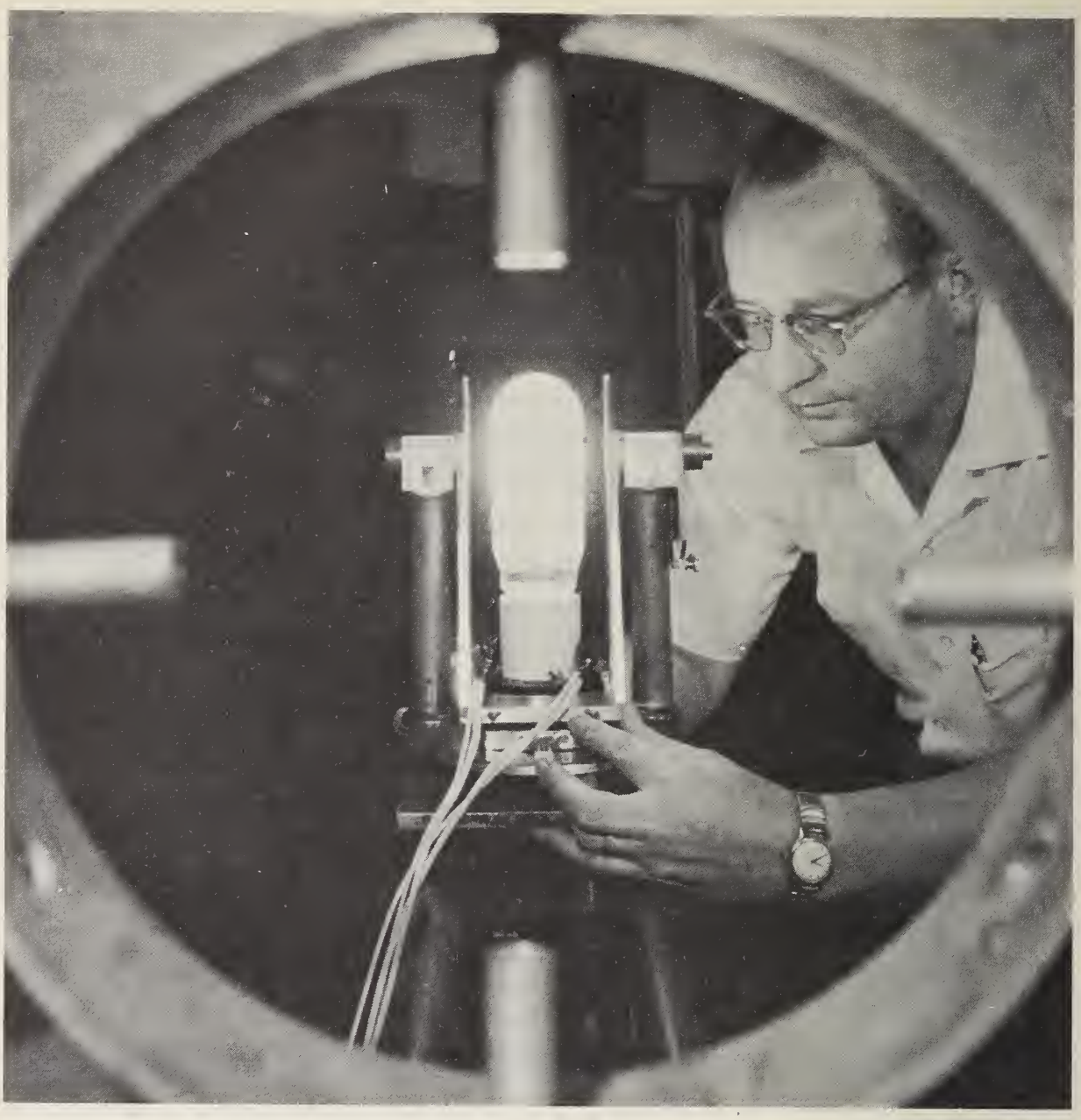


One of the new 100-watt candlepower standards is adjusted on a photometric bar for calibration. The new frosted-bulb standards have proved superior in many respects to the clear-bulb lamp standards previously issued (page 27).

2.3. Heat

Advances in science and technology constantly necessitates determination of temperature with increasing accuracy and extension of measuring techniques to higher and lower temperatures. To provide a basis for precise measurement of heat, the Bureau maintains temperature scales from the lowest to the highest accessible temperatures, and continuously develops and extends these scales. In addition, standards are developed for other heat measurements such as thermal diffusivity, heat capacity, heat of combustion. viscosity, and fuel kinetics.

A broad program of basic research in related critical areas is being conducted to extend these standards. Special emphasis is given to basic studies in standards of temperature measurement, heat measurements, statistical

thermodynamics, molecular structure, high-pressure thermodynamics, low-temperature physics, rheology, and high-temperature processes.

During the past year, these activities were characterized by efforts to obtain new extremes of temperature and pressure, to increase the degree of automation of precision measurements, to extend knowledge of the statistical thermodynamics of dense systems, to investigate the rheological properties of selected materials, and to study the mechanisms of high-temperature processes with greatly improved instrumentation. A broad investigation was initiated on the thermodynamic properties of compounds composed of light elements, and an intensive 3-year program on the behavior of solids containing trapped free radicals will be completed shortly.

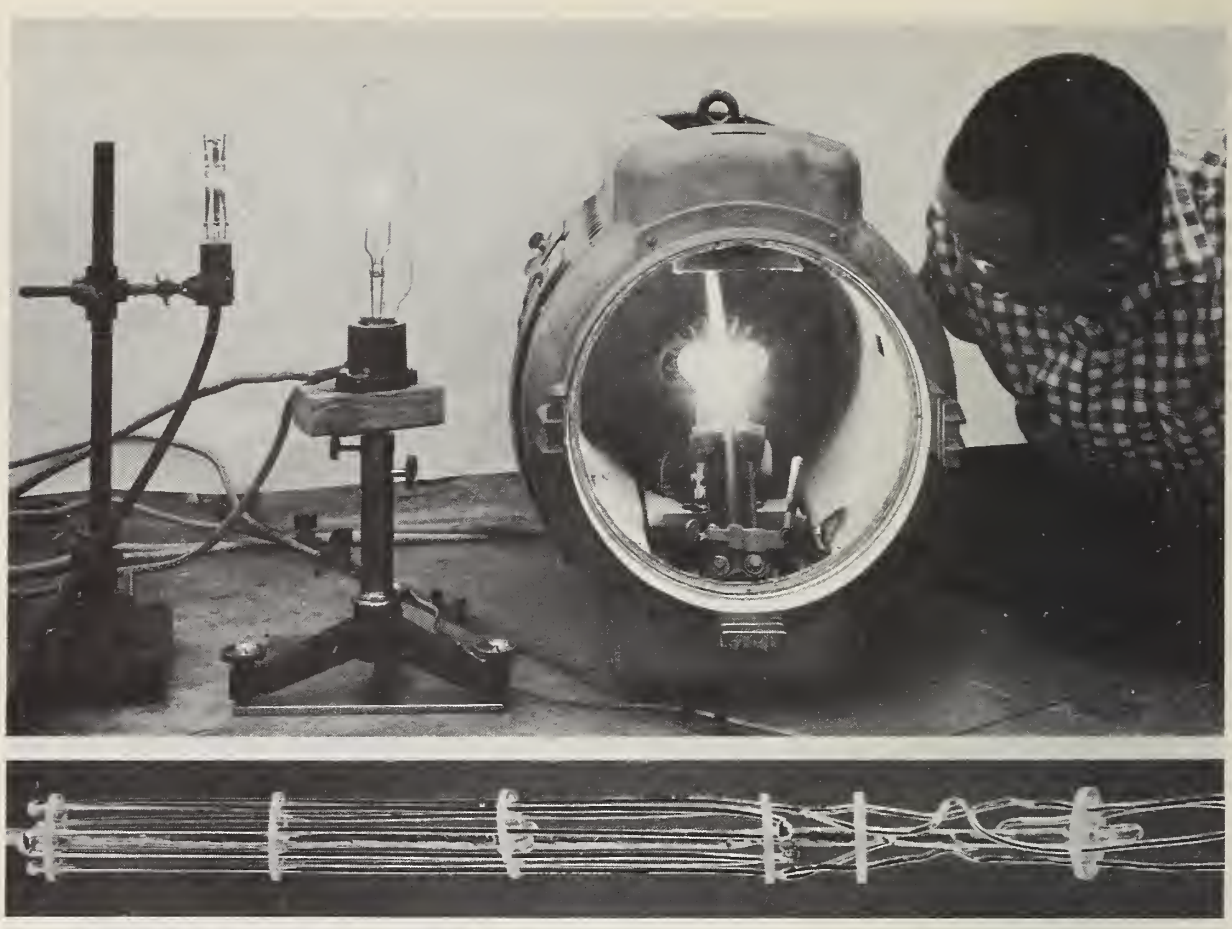
High-Temperature Resistance Thermometry. Since the adoption of the International Temperature Scale in 1927, the platinum versus platinum-10 percent rhodium thermocouple has been the standard instrument used for interpolation between fixed points on the scale from 630.5° to 1,063° C. Because factors inherent in the thermocouple itself and in its use limit the accuracy to about 0.2 or 0.3 deg a better thermometer is needed for accurate temperature measurements in this range.

The unsatisfactory performance of resistance thermometers at high temperature has generally restricted their use. However, the Bureau has designed a suitable resistance thermometer using high-temperature materials. The availability of exceptionally high-purity platinum and high-purity synthetic sapphire (aluminum oxide), which is used as a supporting material for the resistance coil, has made possible this development. The high-purity form of aluminum oxide has the required electrical properties and stability at high temperature and at the same time does not contaminate the platinum.

Although not all of the difficulties associated with high-temperature resistance thermometry have been completely overcome, the platinum resistance thermometers recently developed appear satisfactory for the range 630.5° to 1,063° C. Studies are being continued on the effect of various protecting tube materials over long periods, and on the stability of the thermometers in different atmospheres.

Pyrometer Symposium. To facilitate the exchange of information and ideas on high-temperature pyrometry, a Symposium on the Optical Pyrometer Temperature Scale was held at the Bureau in October 1958. The theme of the symposium, which was sponsored by the Bureau and the Argonne National Laboratory, concerned research on present temperature scales and calibration practices, recent improvements in optical pyrometer techniques and instruments, and the possible use of the temperature scale beyond 4,000° K.

In the past few years, the interest in high-temperature measurements has created a demand for optical pyrometers capable of greater accuracy. This need has raised many questions about procedures for realizing the International Temperature Scale at high temperatures above 1,063° C, and about the calibration, use, and manufacture of optical pyrometers. The symposium gave the users of optical pyrometers in various laboratories an opportunity



Above: **Temperature sources used in calibrating optical pyrometers. A tungsten ribbon-filament lamp (center) provides brightnesses corresponding to temperatures up to 2,400°C. Calibrations are made at 2,800°C with a zirconium arc (left) and at 3,800°C with a carbon arc (right).** ***Below:*** **Temperature resistor of platinum resistance thermometer developed for use from 630.5°C to 1,063°C. It is designed to provide more precise measurements than are possible with thermocouples now in use (page 29).**

to meet with Bureau staff and technical representatives of the pyrometry industry, to exchange ideas, and to discuss problems associated with the calibration and use of the instruments.

Precise Measurement of Shock-Wave Velocity. Investigations are being conducted to utilize the high temperatures existing in shock waves to study the kinetics of reactions occurring in very short periods of time. Thus far, the effort has been devoted predominantly to improvement of the accuracy of methods for determining the velocity of a shock wave, from which the temperature may be calculated.

The sensitivity of detectors for the passage of moderate-strength shock waves in low-pressure gases has been considerably increased by an improved method for preparing thin semiconducting films. Nickel oxide is deposited on glass by a sputtering technique, and the deposit is aged to increase the surface resistivity and the negative temperature coefficient of resistivity. With this method, surface resistivities of approximately 50,000 ohms/square, with negative temperature coefficients of 1.5 percent/deg C are attainable. Thermal response times for detectors utilizing these nickel oxide films are in the order of one microsecond. This quick response enables a more accurate determination of the shock temperature.

Low-Temperature Thermometry. In solid-state physics, as well as in some branches of chemistry, a large amount of research is carried out in the liquid-helium region (1° to 5° K). The success of physical research at low temperatures is dependent upon accurate measurement of temperature. Because the International Scale is defined only down to 90° K, there is a pressing need for a sensitive and reproducible secondary thermometric standard for measurements below 90° K.

To meet this need the Bureau is developing a sound-velocity thermometer based on the velocity of sound in helium gas. A method was developed to make accurately reproducible measurements in the normal helium region, which—because of large temperature gradients and thermal fluctuations—was not possible before. In an extensive study on the behavior of carbon resistors, certain carbon resistors were found to be reproducible to within 0.001 deg, even after repeated cycling between 4° and 100° K. Such high accuracy is needed because the temperature of a dependable isothermal liquid helium bath should be kept within this limit. However, the reproducibility is not maintained if the temperature of the liquid falls below the "lambda point," i.e., if the superfluid phase of the liquid helium is produced. It is speculated that this effect may be connected with penetration of the liquid into microscopic channels within the resistor. Further investigations are in progress.

Viscosity Standards and Measurements. Almost all determinations of viscosity of liquids are made indirectly with instruments which must be calibrated using liquids of known viscosity. A widely accepted calibration standard of liquid viscosity is water at 20° C and 1 atmosphere.

A proposal for the formal adoption of water as a calibration standard was circulated to all member countries of the International Organization for Standardization. Included with the proposal was the suggestion that the viscosity of water (at 20° C and 1 atm) be set at 0.01002 poise, as measured by the Bureau a few years ago.

Although the groups representing most member countries agreed with the proposal, the members from the USSR have objected to adoption of this value. They have submitted reports claiming that water *saturated with air* has a slightly different viscosity than *air-free water*. However, no significant difference in the viscosity of *air-free* and *air-saturated* water has been detected in measurements at the Bureau. Analysis of the Russian reports has raised several questions regarding various aspects of their measurements. These questions are being formulated for transmission to the Russian workers.

Concurrently with this analysis, work is being continued on the development of methods for absolute measurement of viscosity. When a suitable method is developed, it should be possible to redetermine the viscosity of both air-free and air-saturated water in the absolute fashion with sufficient precision to settle the problems.

Significance of Spectroscopic Measurement of Flame Temperature. The development of jet engines and gas turbines has led to the need for basic research on the physical and chemical processes occurring in hot gases and on methods of temperature measurements where usual procedures fail. Detailed spectroscopic studies on well-controlled systems provide the basic information required in this field as well as in upper-atmosphere chemistry and physics, and in chemical kinetics.

Under certain conditions, spectra emitted by excited OH free radicals in flames show the existence of radicals with abnormally high-rotational energy, indicating a temperature as high as 10,000° K. However, the heat released in burning is sufficient to produce a thermodynamic temperature of only about 3,000° K in these flames. Results of this kind have presented a puzzling contradiction for some time, since molecules that have such an excess of rotational energy are known to lose this energy easily in collisions with other gas molecules at lower temperature. In a program sponsored by Wright Air Development Center, the Bureau has resolved this contradiction by demonstrating the existence of a quenching collision process which removes energy from excited OH molecules in the flame so efficiently and quickly that they do not have time to bring their rotational energy into equilibrium with the rest of the flame. Thus the molecules from which emission of light is observed have not had time to interact with other molecules in the flame gases, and the temperature deduced from the OH emission spectrum is not characteristic of the temperature of the flame as a whole.

In these spectroscopic experiments, a flame is illuminated with light which is absorbed by OH radicals in it, and the amount of light reradiated by these radicals is measured. It is found that only a few percent of the absorbed light are reemitted, indicating that most of the excited radicals are deactivated by quenching collisions.

Thermodynamic Properties of the Light Elements. In connection with research on the properties of materials, light-element compounds—important as efficient sources of energy—are presently receiving concentrated attention. Applications for the data may be found in rocket development as well as other defense and industrial fields. Very little basic information exists on the light elements and the little which has been determined does not extend to the high temperatures and pressures necessary in practice.

To fill this need, a comprehensive interdivision program of experimental and theoretical work has been initiated on lithium, beryllium, magnesium, and aluminum—in free form, and in combination with hydrogen, oxygen, nitrogen, fluorine, and chlorine. (See 2.9, p. 83.) The objective of the program, sponsored by the Advanced Research Projects Agency is to secure fundamental thermodynamic properties of the light element compounds. Knowing these properties, the energies and equilibrium properties of the mixtures of these substances can be determined with an accuracy of one percent in solid, liquid, and gaseous phases. It is hoped that this accuracy will be possible in the temperature range from 0° to 6,000° K and in the pressure ranges from 0 to 100 atm. The following methods are being

employed for the investigations: Fluorine calorimetry, thermochemistry, low- and high-temperature calorimetry, halide equilibria, statistical thermodynamics, digital computing techniques, spectra and molecular structure, thermodynamics of refractory substances, and chemical preparation and properties of hydrides. Exploding wire techniques also are being explored to obtain data at the higher temperatures and pressures.

Nitrogen–Fluorine Bond Energy. Chemical oxidizing agents were investigated which have special properties, such as large heat of reaction per unit weight or per unit volume, and safe and convenient handling properties. Compounds in which nitrogen is bound to fluorine are of particular interest in this connection because the relative weakness of the chemical bonds between nitrogen and fluorine, and the great strength of bond which these elements can form in other combinations offer opportunity for liberation of large amounts of energy in suitable reactions. However, the value of the N–F bond energy has not been known with certainty because of limited and apparently conflicting data on the subject, and hence, estimates of reaction energies have been unreliable.

A calorimetric study of the bond energy was successfully completed for the Navy Bureau of Ordnance. From the study of the reactions of nitrogen trifluoride with hydrogen and with ammonia, results indicate the bond energy in nitrogen trifluoride is approximately 66.4 kcal/mole. This work is being extended to other compounds containing N–F bonds to determine the variation of the bond energy in different molecular environments.

Physicochemical Processes in Flames. As part of a basic research program on the physicochemical processes of flames, the spectra of representative fluorine flames are being investigated to establish the structure, fundamental constants and properties of fluorine, and related halogen compounds. For the first time, the vibrational rotation spectra of HF in a fluorine flame have been studied with a high-resolution, grating spectrometer. Despite the formidable experimental difficultes in operating such flames under conditions suitable for spectroscopy it has proved feasible to record the emission over a very wide spectral range and to maintain steady flames for periods up to one day. Because the flame is extremely hot (4,000° K) a large number of hitherto unobserved transitions at high temperatures could be recorded and used to obtain new and highly precise molecular constants.

Statistical Thermodynamics. The development and application of theoretical methods has greatly accelerated in describing and computing thermodynamic and related properties of gases, liquids, and solids. While work in the statistical theory of many natural phenomena which involve time-dependent properties of matter has been increasing, the basic principles are not yet well understood. For this reason the Bureau is attempting to increase knowledge of these principles.

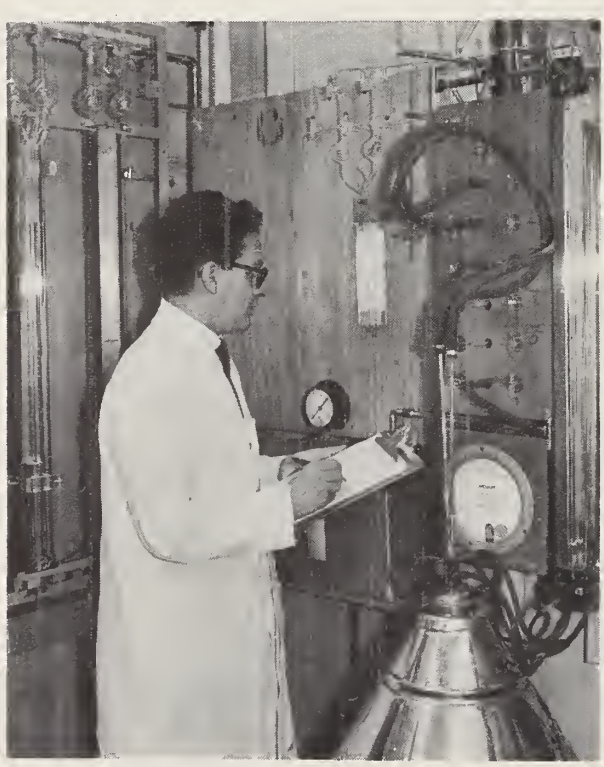
Modern methods for solving "many-body" problems have been applied to a variety of situations such as the equilibrium behavior of a fully ionized plasma in a magnetic field. Modifications which are necessary in a theory

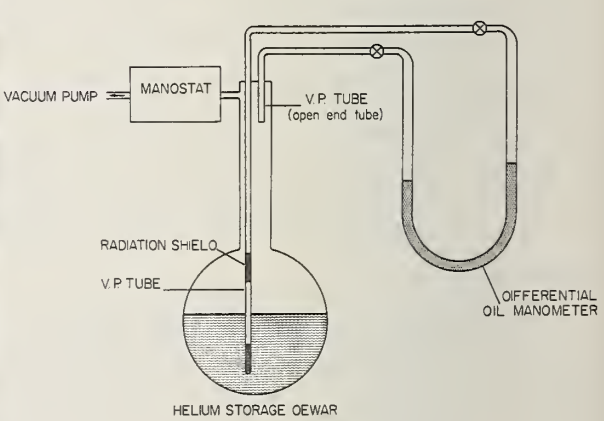
of transport for plasmas because of long range coulomb interactions have been studied. Progress has been made in the description of the low-temperature properties of Bose systems and in the characterization of condensation phenomena using recently developed graph and summation techniques. A study of the fundamental bases of statistical mechanics has been carried out on methods of forming ensembles and the fluctuation dissipation theory has been used to describe relaxation processes in systems subjected to nuclear magnetic resonance.

A collection of approximately 20 high-speed digital computation programs has been developed and is in use for the preparation of tables of properties of gases, liquids, and solids. Using this method, hundreds of pages of thermodynamic properties of dissociated and ionized gases are computed readily. Tables of this kind have immediate application in pure and applied research, and in the design and development of power, propulsion, and other devices. Tables of thermodynamic properties of air and its principal constituents are in preparation over the temperature range of 2,000° to 20,000° K and pressure range of 10 to 10^{-6} atmospheres.

The Nature of Superconductivity. To understand the nature of superconductivity, the Bureau is studying the equilibrium mixtures of normal and superconducting regions in superconducting metals.

For a superconducting material which distorts an applied magnetic field, an "intermediate state" becomes possible. In this state, the metal consists of a complex structure of neighboring superconducting and normal regions. This structure exhibits a definite periodicity—that is, the superconducting and normal regions recur at specific intervals. Recent theories have introduced the concept of a "range of order" in the superconducting state. These theories suggest that the specific arrangement of the regions is closely related to the atomic scale interactions between the electrons of the superconductor.





Scientist checks the vapor pressure in a nearly constant-temperature liquid helium bath developed as part of a project to establish an absolute temperature scale in the range 2° to 20°K. The vapor pressure must be accurately controlled in order to achieve reproducible temperatures (page 31).

The periodic structure is associated with a varying magnetic intensity near the surface of the specimen which may be detected with a bismuth probe. Since the regions are only a few tenths of a millimeter long, it is necessary to use extremely minute probes.

Data for tin cylinders of various diameters and degrees of crystal perfection have been obtained. The results are in qualitative agreement with some aspects of the theory but also demonstrate the inadequacies of the theory in other respects.

Compressibility of Polymers. As part of a program to establish a relationship between rheological properties and structure of materials, the compressibility of polymers is being investigated. A study of the effect of pressure, temperature, and frequency on the dynamic compressibility of a natural rubber-sulfur formulation has been completed. The dynamic compressibility, which includes both the elastic and viscous response to an alternating hydrostatic pressure, shows a typical relaxation behavior as the material goes through the transition from a rubbery to glassy phase. That is, the system requires an observable length of time to respond to sudden changes of force applied to it.

Since the glass transition appears to be closely associated with a kind of free volume available to the molecules of the system, the relationship between the temperature, pressure, and time-scale (i.e., reciprocal of the angular frequency) at which it occurs should assist in a better understanding of the phenomenon.

A 12-percent natural rubber-sulfur compound was chosen for investigation as one which should be fairly typical of rubberlike behavior and which would have a transition in an experimentally accessible range. The measurements of compressibility covered $-25°$ to $+75°$ C, 1 to 1,000 atmosphere, and 50 to 1,000 cycles per sec. As expected, the transition temperature shifts with pressure as well as with temperature, increasing at the rate of about 0.025° C per atmosphere. It is now possible to present a single reduced curve which includes the effects of both temperature and pressure.

Reaction of Chlorine Beams With Nickel at High Temperatures. Studies of chemical reactions between gases and metals at high temperatures can provide information which not only is of great value in understanding surface phenomena, but also has important applications in many phases of high-temperature engineering. Current research in this area, under the sponsorship of the Atomic Energy Commission, includes molecular-beam experiments in which a collimated beam of gas strikes a hot-metal surface. The gas and metal interact to form gaseous reaction products which are directly analyzed in a mass spectrometer placed near the reaction site. The thorough control of reaction conditions achieved with the molecular beam plus the sensitive and specific nature of mass spectrometric analysis make these experiments an excellent source of detailed information on high-temperature surface reactions.

An examination of the chlorine-nickel system between 1,150° and 1,650°

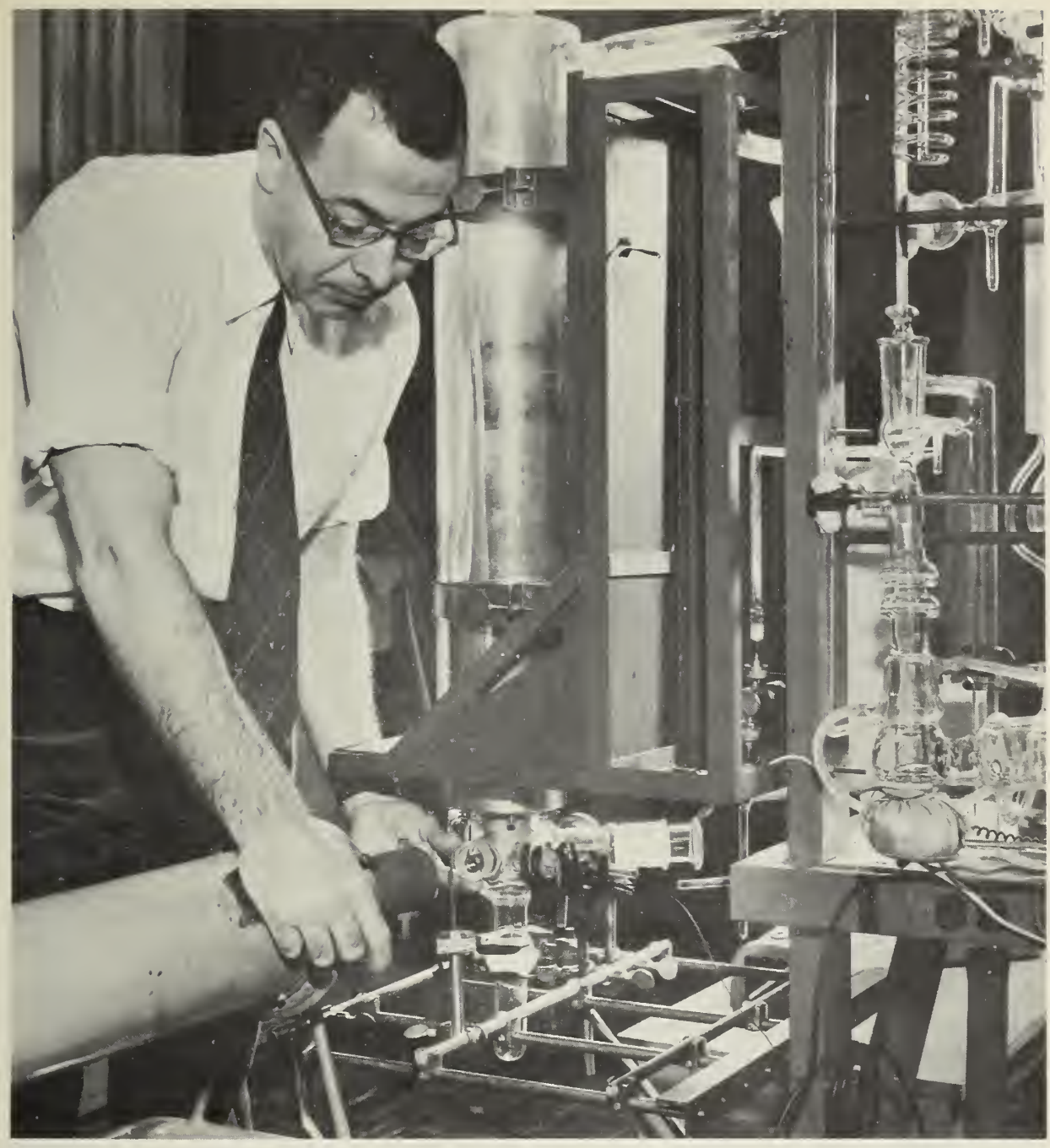
K indicates a rapid reaction rate proportional to the chlorine-beam intensity. NiCl and $NiCl_2$, which are both formed on the nickel surface rather than in gas phase reactions, have been identified as reaction products. NiCl is the only product above 1,430° K, while at lower temperatures the dichloride appears at a rate increasing with decreasing temperature, thus becoming the predominant product at the lower end of the temperature range covered.

In these investigations, particular emphasis is being placed on the type of adsorption process associated with the reaction and on the dependence of chemical rates on the physical constitution of the metal's crystal surface. By using single crystals, the relative reactivity of the principal crystal planes of nickel are being studied.

Free Radicals Research Program. The 3-year program of basic research on the properties of solids containing trapped reactive species is now approaching its planned termination. This program was established in October 1956 as a cooperative venture among government, industrial, and university laboratories with financial support from the Department of Defense. The work of the past year was characterized by the completion of the numerous experiments, and the determination of preliminary results. These experiments and results can be considered under the main categories: Identity and concentrations of trapped species, nature of the solid containing the trapped species, and reactions of the trapped species in the solid.

Spectroscopic investigations have been carried on over the wavelength range from the infrared to the vacuum ultraviolet and various trapped species such as N_3, NH, NH_2, and possibly also O^+_2, have been identified. For the first time, OH in the gas phase was detected by electron spin resonance. Methods of determining the concentration of trapped radicals, such as magnetic susceptibility and electron spin resonance, have been successfully applied. These measurements resolved some of the earlier discordant results and confirmed that the concentration of radicals trapped in solids at low temperature is definitely less than 1 percent, and probably less than 0.1 percent. These results are of particular importance because of the possible use of trapped radicals as a source of energy.

X-ray absorption measurements were used to determine the rate at which gas molecules condense on a cold surface, thus giving clues to the mechanisms of the deposition process of solids containing trapped radicals. To supplement X-ray data, electron diffraction methods were applied for the first time. The X-ray patterns, used to define crystal structure, were obtained from thin films of solids such as nitrogen, condensed at 4° K from the gas phase. Numerous other properties are being determined. For example, the index of refraction of condensed gases has been measured at 4° K. This type of measurement, coupled with the independent determination of the dielectric constant of these materials, has given useful structural information. A fairly precise measurement of the thermal conductivity of nitrogen films condensed at 4° K has indicated an unexpectedly large variation in thermal conductivity, depending on the conditions under which the solid was formed.



This apparatus is typical of many developed to provide new data on the production and properties of free radicals during a three-year program now nearing termination. It is used to study the light emitted by free radicals produced in oxygen rare gas deposits by electron bombardment. A spectroscope is being focused on the cold surface where the free radicals are trapped (page 36).

Much of the research in the Free Radicals Research Program involves low-temperature chemistry. The development of a liquid-helium Dewar vessel which can be rotated at 3,000 revolutions per minute while under vacuum and at 4° K has contributed to these studies. Investigations on chemical reactions occurring in solids at these temperatures have been pursued through a variety of techniques. Perhaps the most informative has been the addition of hydrogen atoms to films of condensed substances. The initial work along these lines—the reaction of hydrogen atoms with solid olefins at 77° K—has recently been extended by reaction studies at even lower temperatures. In particular the observation of a reaction between hydrogen atoms and oxygen molecules at 20° K indicates that the HO_2 mole-

cule may be trapped in the process. Reactions produced in solids at very low temperatures by electron bombardment have also been investigated. (For other free-radicals work, see p. 74, 86).

2.4. Atomic and Radiation Physics

Progress in such fields as civil defense, medicine, biology, and space technology depends strongly on advancements in atomic research. This application of basic discoveries to practical problems places an ever-increasing demand on the Bureau for information and services. To meet this demand, efforts are concentrated primarily on providing more detailed and reliable data on the properties of radiation, atoms, nuclei, and subatomic particles, and the various interactions they undergo. Research tools such as spectroscopy, solid-state physics, and bombardment studies are used to probe the behavior of particles and radiation.

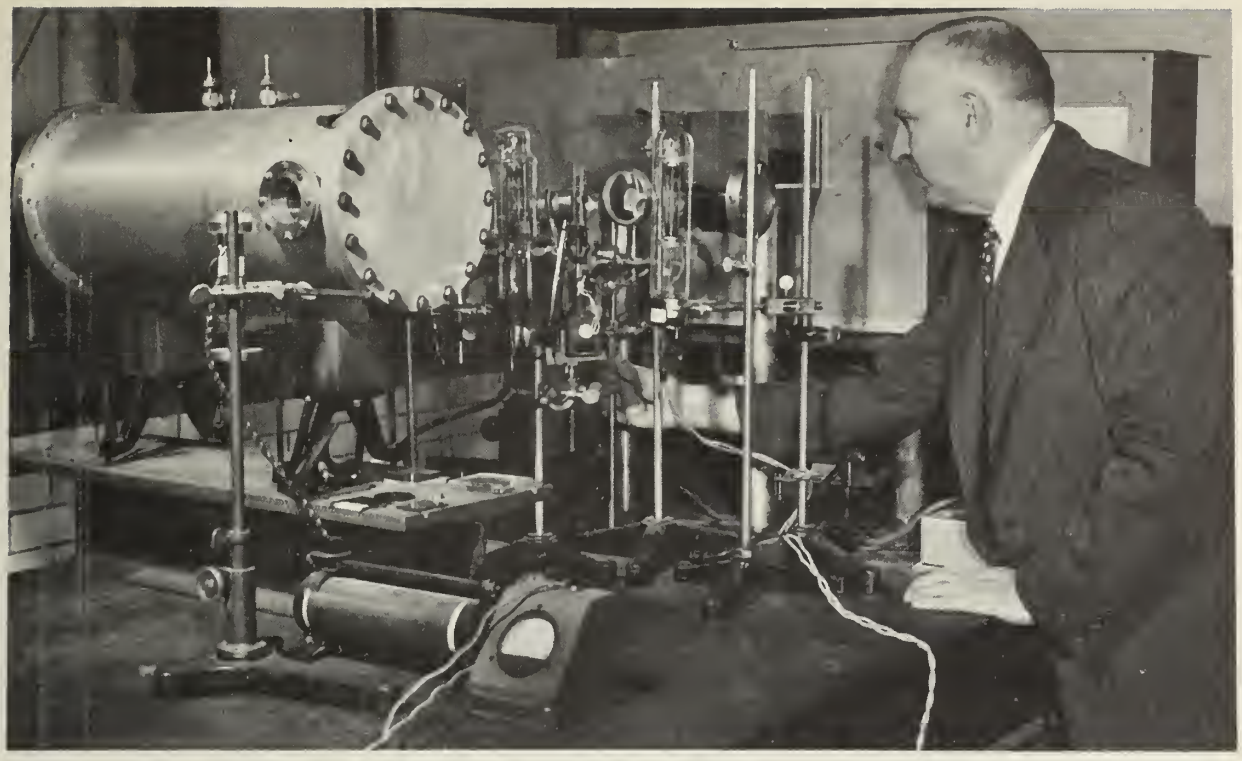
In addition to providing a clearer understanding of radiation and nuclear, atomic, and subatomic particles, the research leads to new and better ways for control and measurement. Complementary work, which follows directly from the data obtained in basic studies, is aimed at developing new kinds of standards and improving the accuracy of existing standards.

Spectroscopic Research. Analysis of the light emitted by excited atoms is a widely used method for obtaining information on atomic structure. The Bureau uses this technique to derive atomic energy levels and configurations for individual atoms. These data are in constant demand by physicists, chemists, spectrographers, and astronomers. Some of the most recent work in this area was done on hafnium. By observing the spectra emitted by this element in a microwave-excited quartz tube, 6,200 lines were ascribed to hafnium. Similar excitation sources were developed for studies on the rare earth elements. Ytterbium is presently being analyzed by spectroscopic techniques.

A description and analysis of the first spectrum of iodine was also completed, and work on the second spectrum of iodine and the first and second spectra of tantalum is well under way. Further observations were made of the complex spectrum of neutral thorium atoms in the far infrared. Studies of the effect of a magnetic field on this spectrum have led to the discovery of 150 new energy levels.

The wavelengths of spectral radiations are usually measured in the earth's atmosphere, but to derive atomic or molecular energy levels, it is necessary to convert them to vacuum values. For this purpose a new Table of Wavenumbers has been prepared. It gives, with high accuracy, the index of refraction of the atmosphere, change in wavelength, and the number of waves per centimeter in vacuum of any wavelength from 2000.0000 A to 1 mm measured in air.

Work is also under way to provide a table of the relative intensities of the spectral lines of 70 elements under standard conditions. The results of a new calibration of the copper arc reference standards have been applied



This high-resolution infrared spectrometer provided data for the calculation of previously undetermined molecular parameters (page 40).

to more than 10,000 lines in the interval 2400 to 3300 A to obtain accurate intensities.

Rydberg Constant Confirmation. The presently accepted value for an important atomic connective, the Rydberg constant, was recently substantiated through spectroscopic studies at the Bureau. The confirmation resulted from an examination of earlier work which gave a value in conflict with the Rydberg constant in use today. The error in the earlier determination was found by the Bureau to be in the value used for the 5016 A line of helium, the reference for measuring the transitions which form the basis for the Rydberg calculation.

Precise interferometric measurements were therefore made for nine strong He I lines relative to two accurately known lines of mercury-198. The wavelength of the 5016 A line was found to be 5016.6782 ± 0.0003 A in air. This value was used in reevaluating the earlier calculations of the Rydberg constant, bringing the value into line with the one presently in use. This constitutes, in effect, an independent confirmation of the Rydberg constant, which since 1952 has been based on the work of only one set of observers.

Astrophysics. An analysis was made of data on the spectrum of Jupiter, obtained at Mauna Loa, Hawaii, in 1957. Results include the first detailed measurements of the structure of the NH_3 and CH_4 bands in the red region of the spectrum, and verify the presence of H_2 and of a more complex molecule, probably N_2O_4, in Jupiter's atmosphere.

Attention has also been devoted to the preparation of a new manual of solar spectrum wavelengths. This project is being carried on in collaboration with the Utrecht Observatory in the Netherlands, at the request of the International Astronomical Union. Revised identifications of atomic and

molecular lines will be included, as well as excitation potentials and other data on atomic lines in the solar spectrum.

To supplement the basic data on quantum structure already available in the volumes of Atomic Energy Levels, tables of "multiplets" are being prepared. These tables include observed laboratory wavelengths and intensities, excitation potentials, and term designations for the lines of individual spectra.

High-Resolution Infrared Spectrometer. An improved grating spectrometer capable of extremely high resolution in the infrared was put into operation. This instrument can resolve the fine structure of previously unresolved infrared bands. This provides a means for investigating larger molecules in the infrared and for determining molecular constants. The spectrometer proved successful in separating the components of overlapping bands such as those of atmospheric water vapor and ammonia. It was also used to measure the spectrum of methane in a program conducted for the Air Force and to measure the spectra of deuterated methanes and deuterated ammonias in work for the Atomic Energy Commission.

Radiometry. To provide an absolute standard for ultraviolet radiation, the Bureau built a graphite blackbody, which it is presently calibrating. This blackbody can withstand very high temperatures and is therefore capable of emitting measurable amounts of ultraviolet radiation. The successful development of such a radiator suggests that the radiation standard for the ultraviolet spectral region can at last be placed on a fundamental basis.

A series of precise measurements on the wavelengths of infrared bands was also carried out to provide reference standards in this spectral region. This work was done in cooperation with the International Commission of Molecular Spectroscopy.

Solid-State Research. To help provide data needed for the effective application of semiconducting materials, the Bureau conducts a broad program of solid-state research. During the past year emphasis has shifted somewhat from the intermetallic compounds to the oxide semiconductors. For example, the electrical conductivity, Hall effect, and thermoelectric power of titanium dioxide were measured over a wide temperature range. From these electrical property measurements it was possible to obtain information on the conduction mechanism in the single crystal samples studied. The behavior of the third electrons was found to constitute a borderline case between the band conception and the localized level model. Other studies on titanium dioxide include optical absorption, photoconductivity, paramagnetic resonance, magnetic susceptibility, and dielectric constant and losses.

During an Air Force-sponsored investigation of carrier lifetimes in semiconductors by means of photoconductive and photo-electro-magnetic effects, it was found that these phenomena are sometimes overshadowed by thermal effects. An important parameter involved in such cases is the thermal diffusivity. The Bureau found that efficient methods for measuring this quantity can be based on the determination of the a-c bolometric and Nernst effects. These methods are applicable to small samples and therefore con-

stitute an important contribution to the rapidly growing field of research on thermoelectric devices.

Electron Scattering. The Bureau's program in electron physics is devoted to a study of the free electron and its interactions with various materials. Scattering experiments form a very large part of this research. During the past year, for example, systematic studies of electron scattering for the Atomic Energy Commission have provided information on both elastic and inelastic scattering of electrons in solids and vapors. Measurements on sodium and potassium have revealed the presence of a low-lying loss which had not been observed in previous measurements. Studies also revealed a change in the characteristic energy low in aluminum as the temperature was lowered to the liquid helium range. This change was larger than that expected from the change in the lattice spacing. Continued work indicated that this may be due to strains introduced in the films bombarded. Measurements of the characteristic energy losses in evaporated carbon and natural graphite have shown that there is a difference in the energy losses for these two forms of carbon. Work is now in process to determine if the energy loss in evaporated carbon can be changed by annealing the carbon to the graphite form.

In another project sponsored by the Office of Naval Research, the elastic scattering of electrons in metal vapors is being used to study the velocity distribution in an atomic beam reflected from a surface. The method consists of passing an electron beam at right angles through an atomic beam and detecting only the electrons which have been scattered by the atomic beam. To measure velocity distribution, the atomic beam is chopped with a rotating disk and the electron beam is pulsed. From these two time constants and the rate of arrival of the atomic beam bunches, the velocity can be determined.

Electron Polarization. Electron beams produced photoelectrically from permanently magnetized iron and nickel films were examined for electron polarization by Mott scattering at 120 kev. A definite upper limit for the obtainable polarization asymmetry was fixed at around 3 percent under the present conditions of the experiment. Observations will be repeated and extended under ultra-high vacuum conditions to complete a search for the very high polarization predicted in photoemission from magnetic materials.

Electron Instrumentation. In both electron spectroscopy and mass spectroscopy, a monochromatic source of electrons is a highly desirable feature. To attain such a source of electrons, an instrument which is effectively an electron monochromator has been constructed. An electron filter lens is used to reduce the number of electrons of low energy. To reduce the high-energy electrons in the electron beam, the beam is modulated with a 40-cycle signal whose amplitude determines the degree of monochromatization.

An electron diffraction apparatus was constructed for the purpose of obtaining high resolution diffraction patterns. A 10-micron electron beam can be obtained on the photographic plate at a distance of 70 cm from the

final lens. Zinc oxide patterns were obtained which showed diffraction spots down to 5 microns in size. Kikuchi patterns have been obtained for single-crystal mica and graphite.

Low-Temperature Electron Bombardment. Studies have been made of the production of free radicals in condensed nitrogen gas by electron bombardment, sponsored by the Department of Defense. These results have led to the theoretical interpretation that a weakly bound triatomic molecule of nitrogen is an emitting species. In addition, an electron diffraction investigation was made of the structure, size, and alinement of crystals in condensed nitrogen as a function of the gas-flow rate and the substrate temperature.

Chemical exchange reactions at very-low temperatures induced by electron bombardment have also been studied at the request of the Department of Defense. Initial attempts were made to study the reaction between hydrogen and deuterium molecules, and later a successful measurement of the *g*-value was made by bombardment of a solidified mixture of nitrogen-14 and -15.

Physics of Negative Ions. Negative ions play an important part in the thermodynamics of gases at the high temperatures reached in rockets and explosions as well as in astrophysical phenomena. To study the structure of negative ions, the Bureau employs a photodetachment technique. This special type of photoelectric absorption formed the basis for detailed investigations of the H– ion. The relative photodetachment cross section for this negative ion was determined from 4000 to 16000 A with a precision of about 2 percent, and results were compared with theoretical calculations. Other studies include theoretical calculation of the cross section for inelastic collisions with electrons which gave a surprisingly large value, and experiments

Improvements were made in standards of radioactivity (page 44). *Left:* A radiation balance is used to measure the rate of energy emission from a radium source used in preparing the new 10^{-9} and 10^{-11}g radium solution standards. *Right:* Tank of manganese sulfate used as a moderator in calibrations of the National Standard Photoneutron Source.

on the electron-H– interaction, in which photodetachment signals were detected.

The detachment spectra of OH– and OD– were also measured as a basis for a precise determination of the molecular constants of the hydroxyl negative ion. The cross section of these detachments, which initially appeared very simple, was found to have a complicated structure. Further studies will be made using a higher optical resolving power.

Calculations of the approximate value of the radiative attachment cross section of electrons to the O_2 molecule were made. The results, combined with other data, were then applied to a study of ionospheric ionization produced by abnormal increases in cosmic radiation accompanying solar flares.

Atomic Standards of Frequency. Hyperfine and Zeeman resonances in cesium and rubidium vapors were investigated to determine line width, pressure and temperature shift, and relaxation mechanisms. As a part of these studies, carried out in cooperation with the U.S. Naval Research Laboratory, it was found that the frequencies in cesium vapor cells remain stable to better than 4 parts in 10^{10} over a period of six months. Hyperfine line widths in rubidium as narrow as 20 cycles per second (cps) at 6,000 Mc were observed, and buffer gas mixtures were obtained in which the hyperfine frequency is either pressure or temperature independent. Studies of low-frequency Zeeman transitions, carried out by the Bureau at the Fredericksburg Magnetic Observatory of the U.S. Coast and Geodetic Survey show that lines as narrow as 3 cps can be obtained with an eicosane-coated sample and lines as narrow as 8 cps for several buffer gas samples. Two rubidium vapor atomic clocks are presently under construction (for other work in this area see 2.15, p. 123).

Scintillation Counting of Neutron Emission Rates. In determining the neutron-emission rate of "radioactive" neutron sources, the source is suspended in a manganous sulfate bath, neutrons are captured by the manganese, and the Mn^{56} activity is normally counted by a Geiger-Muller counter. A scintillation counter has recently been used instead to provide higher count rates and allow the accurate calibration of weaker sources than was previously possible. In this way, a more precise value has been obtained for the ratio of the National reference standard source to the National standard source.

Penetration of Gamma Radiation. Extensive computations were performed this past year on data relevant to the analysis of the shielding properties of structures against fallout radiation. These data formed the basis for considerable progress toward development of rules and charts for structure shielding engineering. This program is being sponsored by the Office of Civilian Defense Mobilization, the Atomic Energy Commission, and the Department of Defense jointly, and the results are already being widely used in these agencies in making shielding estimates of various kinds.

One study of gamma-ray penetration for the Civil Effects Test Group of the Atomic Energy Commission included postdetonation measurements at

the Nevada Proving Grounds. This on-the-scene experimental data on the effects of fallout was one of the first attempts to make fields measurements in arrangements which lend themselves to a theoretical approach. By allowing an adequate comparison between experimental data and theoretical calculations, this work provides a basis for extending theory to configurations more elaborate than those for which predictions are now possible. Results of this investigation should thus be very useful in the development of suitable shelters against radiation from nuclear weapons.

Radioactivity Standards. The standardization of radioactivity measurements throughout the country depends primarily upon the distribution of samples with certified activities and the performing of tests and calibrations. During the past year, 715 samples were issued, 40 radium assays were made, and 400 radon tests were carried out. The Bureau also added a new series of 10^{-9}- and 10^{-11}-g radium standards for distribution to replace a less-accurate earlier series. A measurement of these standards at the Physikalisch-Technische Bundesanstalt gave a value which agreed within 0.3 percent with the Bureau's certified value. Other international intercomparisons were carried out with 10 countries in North and South America, Europe, and South Africa.

A recalibration of the Bureau's carbon-14 standards formed the basis for a new determination of the half-life of carbon-14. A half-life value was also obtained for radium-226 from a measurement of rate-of-energy emission.

X-ray Studies. Studies, supported by the Atomic Energy Commission, are being carried out to obtain experimental data which can be used to describe X-radiation under any set of experimental conditions and to check theoretical predictions. As a part of this work, the linear polarization of X-rays produced with 0.5 and 1.0 Mev electron were experimentally determined at different emission angles and for different regions of the X-ray spectrum. Results verify interesting reversal characteristics of the polarization and point up certain differences with theoretical predictions. Detailed studies of the X-ray production process are also underway to obtain information on the angular distribution of recoil electrons as well as on the polarization effects that occur in the process.

Linear Electron Accelerator. In recent years the number of industrial installations utilizing intense high-energy electron beams for the processing of materials have increased greatly. In order to insure the economical and efficient use of this new tool, the interactions of high-energy electrons and X-rays with matter must be understood. Among the important processes are photonuclear interactions, absorbed dose measurements, radiation energy measurements, and radiation characteristics.

To extend the Bureau's capabilities in this area of basic research, a linear electron accelerator has been designed that will produce electron beams with energies of 40 Mev and power output of 40 kilowatts. This electron beam power is 100,000 times more than that obtainable with the radiations source presently in use at the Bureau.

High-Energy Radiation. In the research program conducted with the Bureau's 50-Mev betatron and 150-Mev synchrotron significant progress was made toward a better understanding of the basic interactions of high-energy electrons and X-rays with matter. Of interest to users of betatrons and synchrotrons was a new evaluation of the bremsstrahlung cross section at the high-frequency limit. This evaluation, based on theoretical estimates and experimental measurements, indicated the presence of a finite number of photons at the high energy tip of the bremsstrahlung spectrum.

In work supported by the Atomic Energy Commission an improved calibration was made of the Bureau's bremsstrahlung monitor. A calorimetric means was employed in this recalibration and it is felt that the uncertainty in the calibration between 10 and 170 Mev is less than 2 percent. In other work supported by the AEC a detailed study was made of the shape of the photoneutron yield curve for the nuclei around the doubly magic nucleus Pb^{208}. The nuclei studied were Pb^{206}, Pb^{207}, Pb^{208}, and Pb^{209}. It was found that the neutron production cross sections for these nuclei did not have the simple Lorentz shape expected on the hydrodynamic model for closed shell nuclei. The deviations observed are probably an indication of the extremely low-level densities of these nuclei.

A detailed study was also made of dosimetry measurement systems, and results were presented at the 1958 International Conference on the Peaceful Uses of Atomic Energy.

Gamma- and X-ray Calibrations. Instruments used as laboratory standards for gamma-ray measurements in industry, science, and medical research are calibrated against the Bureau's cavity ionization chamber. To improve the accuracy of these calibrations, an intercomparison was made between the results of this usual method and those obtained with a free-air chamber. The free-air chamber while more difficult to use gave results that agreed within 1 percent with those from the cavity ionization chamber for cobalt-60 and cesium-137 gamma rays. In addition, a basis was provided for refining the corrections applied to calibrations, resulting in a considerable improvement in overall accuracy.

The need for improved low-energy X-ray standards has been increasing with the extensive use of low-voltage medical X-ray equipment and the need for measurement of low-energy stray X-rays from equipment employing electron tubes. Accordingly, investigations were carried out to obtain the design characteristics of a free-air parallel-plate ionization chamber suitable for X-rays produced in the range 20 to 100 kv. A chamber was constructed, tested, and intercompared with the present free-air standard chamber over the appropriate voltage range. The comparison indicated satisfactory agreement and the new free-air standard together with the older 250-kv standard permits X-ray calibrations over the range 20 kv.

Dosimetry. The oxidation of ferrous to ferric ions in a ferrous sulfate solution is a widely used technique for dosimetry of X- and gamma rays. The Bureau has investigated "chemical dosimetry" with special reference to the effect of factors such as purity and age on the ferric ion yield.

An investigation of the behavior of silicon cells exposed to high doses of cobalt-60 gamma rays showed that the photovoltage and photocurrent decay with time, probably because of radiation damage. The concurrently decreasing electrical resistance of the cell could, after the irradiation, be restored stepwise to its original value, by annealing with increasing temperatures up to 250° C. The measurements will be continued under different experimental conditions.

Photographic films have been used extensively for the measurement of radiation, although they do not have all of the desired characteristics for such measurements. Experience with this type of dosimetry indicates the importance of a thorough understanding of the fundamental processes involved for the proper interpretation of results. Accordingly, studies were continued of several effects. It was established that the developability of the latent image on the ascending branch of the characteristic curve increased with exposure rate. Attempts are now being made to locate a region where developability decreases with increasing exposure rate.

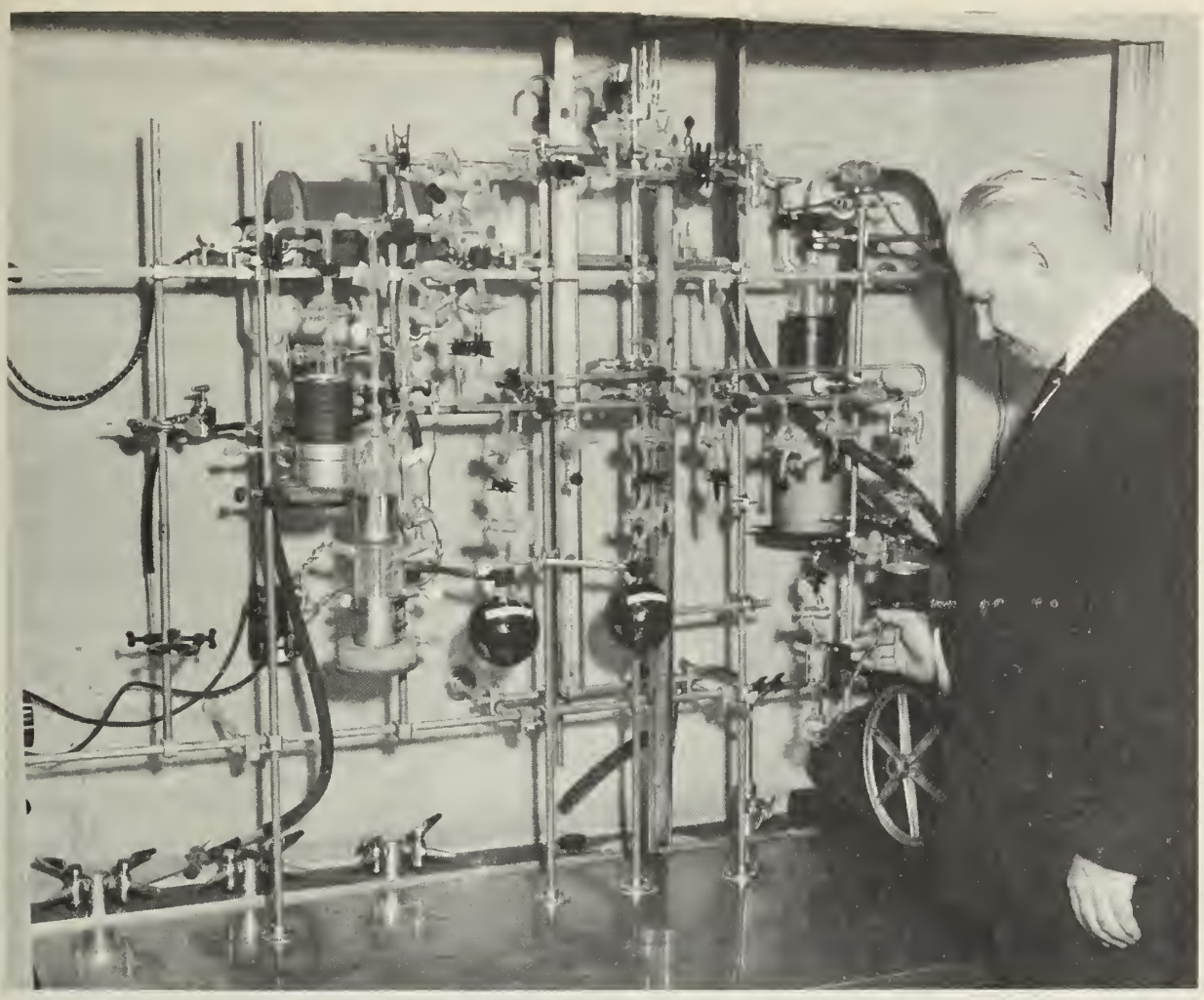
Methods for measuring very high gamma-ray doses are of interest in connection with food sterilization and radiation damage effects to materials. A new method was evolved, by which ordinary commercial dosimeter film can be used for gamma-ray measurements in the range from about 2×10^4 to 5×10^7 r, with a precision of about 5 percent. This method utilizes the latent image without development and employs narrow bands of red light for determining the opacity of the exposed film.

2.5. Chemistry

Basic and applied research in many fields of chemistry is being conducted by the Bureau. Fundamental studies include such activities as developing and improving methods for the measurement of the chemical properties, composition, and behavior of substances; preparing standard substances of known composition or properties; making accurate measurements and collecting data on chemical systems; studying the properties of molecules and atoms in their relation to chemical reactions, and providing technical and advisory services.

The special investigations pursued during the past year in inorganic, analytical, organic, and physical chemistry included studies of new methods for chemical analysis by emission and absorption spectroscopy as well as by conventional chemical means. Substances of high purity were prepared and methods of analyses developed, and radioactively labeled sugars were synthesized. Different types of standard samples were produced and certified, chemical constants of thermochemical data determined and tabulated, and the mechanisms of organic reactions and photochemical processes investigated.

Analysis of Tritium-Labeled Compounds. Tritium is the radioactive istotope of hydrogen, a constituent of nearly all organic compounds, and can enter into the same chemical reactions as hydrogen. In the form of tritiated water or other tritiated reagents, tritium can react with a wide vari-



General-purpose manifold for handling tritium in a closed system was developed to facilitate the synthesis of tritium-labelled carbohydrates. The radiation emitted by the tritium makes it possible for scientists to determine the amount and location of the carbohydrate in any stage of a chemical reaction, and in this way to study the role played by individual molecules in the process **(page 46).**

ety of organic compounds. A few tritiated starting materials enable the chemist to prepare numerous radioactive compounds. Once incorporated in a stable molecule as a substitute for hydrogen, the isotope serves as a "tag" that can be used to trace the course of an atom or a molecule through an entire series of complex processes. Despite these promising features, tritium has not yet received the attention that its properties, as a research tool, warrant, because of a lack of convenient methods for its analysis. If a radioisotope is to have maximum usefulness in chemical and biological studies, it must be possible to measure its radioactivity rapidly and simply.

As the first step in a program, sponsored by the Atomic Energy Commission, to synthesize tritiated sugars and sugar derivatives, a convenient analytical method was developed for determining tritium in water-soluble, nonvolatile materials. This simple method requires no special training of personnel and no elaborate equipment. In essence, it consists of combining the radioactive substance with a solution of a thickening agent, carboxymethyl-cellulose. This mixture is then converted to a film, on a counting plate, and its radioactivity is assayed with a windowless, gas-flow, proportional counter. The amount of tritium present is calculated from the net

count, the weight of the film, and an empirical constant (determined with a substance of known activity). By this procedure, one-billionth of 1 milligram of tritium can be readly determined.

The synthesis and distribution of carbohydrates position-labeled with radioactive tritium is now well underway. The availability of these substances together with the new method of tritium analysis is expected to stimulate the application of tritium in biological and chemical research.

Acid Strengths in Benzene. With the increasing use of monaqueous solvents in chemistry, it has become ever more important to understand how the behavior of acids and bases is affected by the nature of the solvent employed. Two solvents which represent almost the extremes in their effects on dissolved acids and bases are water and benzene. The comparative inertness of benzene makes it one of the best solvents to use in studying the nature of interactions between dissolved acids and bases, including various manifestations of hydrogen bonding. Acids are present in benzene almost exclusively in the molecular state, because benzene is only feebly basic and has a low dielectric constant. In contrast, interactions of hydrogen bonding are masked in water because this solvent itself is associated in various ways with the solutes. The presence of acids in water solution is indicated by the ions which are formed as a result of two properties of water—its ability to function as a base and its high-dielectric constant.

The Bureau has developed a spectrophotometric procedure for measuring relative strengths of carboxylic acids in benzene, using diphenylguanidine as the reference base, together with an indicator acid. This procedure was applied to benzoic acid and 39 substituted benzoic acids, and the results were correlated with existing data for the relative strengths of the same acids in water and alcohols. Valuable insight was gained into the role of water in modifying the strengths of certain acids. The data on acidities in benzene have been found useful elsewhere in the evaluation of resonance effects on reactivities of benzene derivatives and in correlating ultraviolet absorption spectra with molecular behavior.

Determination of Phosphate, Silicate, and Arsenate. The separation and determination of small amounts of phosphate, silicate, and arsenate when they occur together in solution has long been a difficult problem. However, a rapid, accurate method has now been developed for quantitatively separating and determining these ions. On the addition of ammonium molybdate, the three ions form heteropoly molybdate complexes, which can be extracted selectively at high acid concentrations. First the phosphate complex is extracted with ethyl ether, then the silicate complex with butanol, and finally the arsenate complex with methyl isobutyl ketone. Each of these complexes, when reduced with stannous chloride, produces a blue solution. The optical density of the solution, measured with a spectrophotometer, is referred to a calibration curve to determine the amount of the element present in the original sample. The method should be useful in controlling the quality of such materials as chemicals, metals, glasses, and water which contain these salts as impurities.

Separating Metallic Elements in High-Temperature Alloys. The metallic elements tungsten, molybdenum, niobium, tantalum, titanium, and zirconium are becoming increasingly important in the nuclear reactor, missile, and high-speed aircraft fields. Moderate amounts of these elements are added to metallurgical alloys to improve specific physical properties—particularly heat resistance. Because of the complex composition of these high-temperature materials, spectrographic and X-ray methods are used to control their quality in production.

Chemical procedures are being established for the analysis of standards used in calibrating these spectroscopic and X-ray instruments. By incorporating ion-exchange columns, two detailed procedures were developed for the separation and determination of niobium and tantalum in titanium-base alloys and of titanium, zirconium, niobium, and tantalum in complex alloys. Until recently it had not been possible to separate these metals in alloys quantitatively because these transistor elements belong to the same or adjoining groups of the periodic table and thus behave similarly. However, this difficulty was overcome by a three-step procedure based on the formation of metal-fluoride complexes which have different properties.

Air Pollution. Air pollution presents a problem of great importance. Foreign substances discharged into the atmosphere from a variety of sources affect health and comfort, plant and animal life, and the use and durability of many products. The analysis of the atmosphere and the determination of the origin of the contaminants is particularly difficult because of their very low concentrations and the wide variety of reactions between them.

Fundamental studies of the photochemical processes related to air pollution are being conducted under the joint sponsorship of the Department of Health, Education, and Welfare, and the Bureau. These studies are part of a larger program directed toward obtaining fundamental knowledge of elementary chemical reactions and the mechanisms of energy transfer. Processes involving very reactive species such as free radicals and excited molecules are of particular interest. For this reason, the primary dissociative processes were extensively investigated for several compounds thought to dissociate exclusively by molecular rearrangement. However, results have shown that free radicals are formed in the primary processes.

Molten Salt Studies. Since electrolysis of molten salts is a promising method for depositing coatings of such refractory metals as titanium, molybdenum, or tungsten, the Bureau is studying the electrochemical properties of molten salts for the Atomic Energy Commission. During this investigation a reference electrode consisting of a porcelain envelope and a silver–silver chloride internal element, was developed. However, its applicability is somewhat limited by inadequate knowledge of liquid junction potentials in fused salts. The same porcelain that is used as an envelope for a molten salt reference electrode may serve as a sodium ion conductor. This envelope completely protects the silver electrode from contamination by the molten salt and is unique in its low-electrical resistance to the passage of sodium ions. The electrode can be used at temperatures up to the melting point of

Left: **Samples of benzene with controlled amounts of impurity are packaged in a vacuum system. The vacuum transfer system assured the identity of the 42 samples distributed for an international comparison analysis.** ***Right:*** **Analyzing alloys containing minute amounts of titanium, zirconium, niobium, and tantalum. A relatively simple method based on the formation of metal-fluoride complexes was developed for this analysis (pages 51, 49).**

silver and is currently being employed to measure the transference numbers of ions in molten sodium salts. In addition to the value of the transference numbers in interpreting liquid junction potentials, these data are also important in forming theories of structure, electrical conduction, mutual solubility, and other properties of fused salts.

Abrasive Jet. The degree of abrasion resistance of organic and inorganic coatings is an important consideration in the design and preparation of protective coatings. Because this property was difficult to measure accurately, the Bureau developed the abrasive jet method a few years ago. With this procedure, abrasion resistance is measured in terms of the time required for a small jet of fine abrasive particles to wear away the coating on the underlying material (substrate). Conditions of distance angle, pressure, and abrasive flow are closely controlled.

The ease and reliability of the measurement has recently been improved. For example, abrasion tests were conducted on a series of prefinished hardboard materials used for wall paneling. In these tests, the jet abrader accomplished in 30 minutes, with superior performance, a task which required many hours of testing by the widely used ASTM falling sand method.

The abrasive jet method is inherently free from errors caused by such

factors as reuse of abrasive, heating of substrate, clogging of abrading wheels, and uncertainty of end point. Its basic simplicity, speed, and reproducibility, as well as its use with a reference material, promises better interlaboratory agreement than was possible before in measuring abrasion resistance.

Thickness Gage. As new guns are developed with higher rates of fire and muzzle velocity, satisfactory performance and life for the bore of the barrel depend more heavily on a suitable coating to protect the steel from high-temperature effects, mechanical wear, and erosion by powder gases. Chromium plate of the proper thickness and with the proper physical characteristics is one of the best materials for providing the necessary bore protection.

Because the thickness is an important factor in the quality of these gun barrels, the Bureau, in a program sponsored jointly by the Army and Navy, has modified and adapted the "Dermitron" gage for measuring the thickness of chromium plate in gun bores. The device is capable of measuring thickness up to 0.02 in. in caliber .30 bores (0.30 in. diam.), with tube lengths up to several feet. Electroplated coatings of chromium and other metals are extensively applied to the internal surface of tubes for use in various process industries. The gage can be readily adapted to the measurement of coating thickness in such tubes.

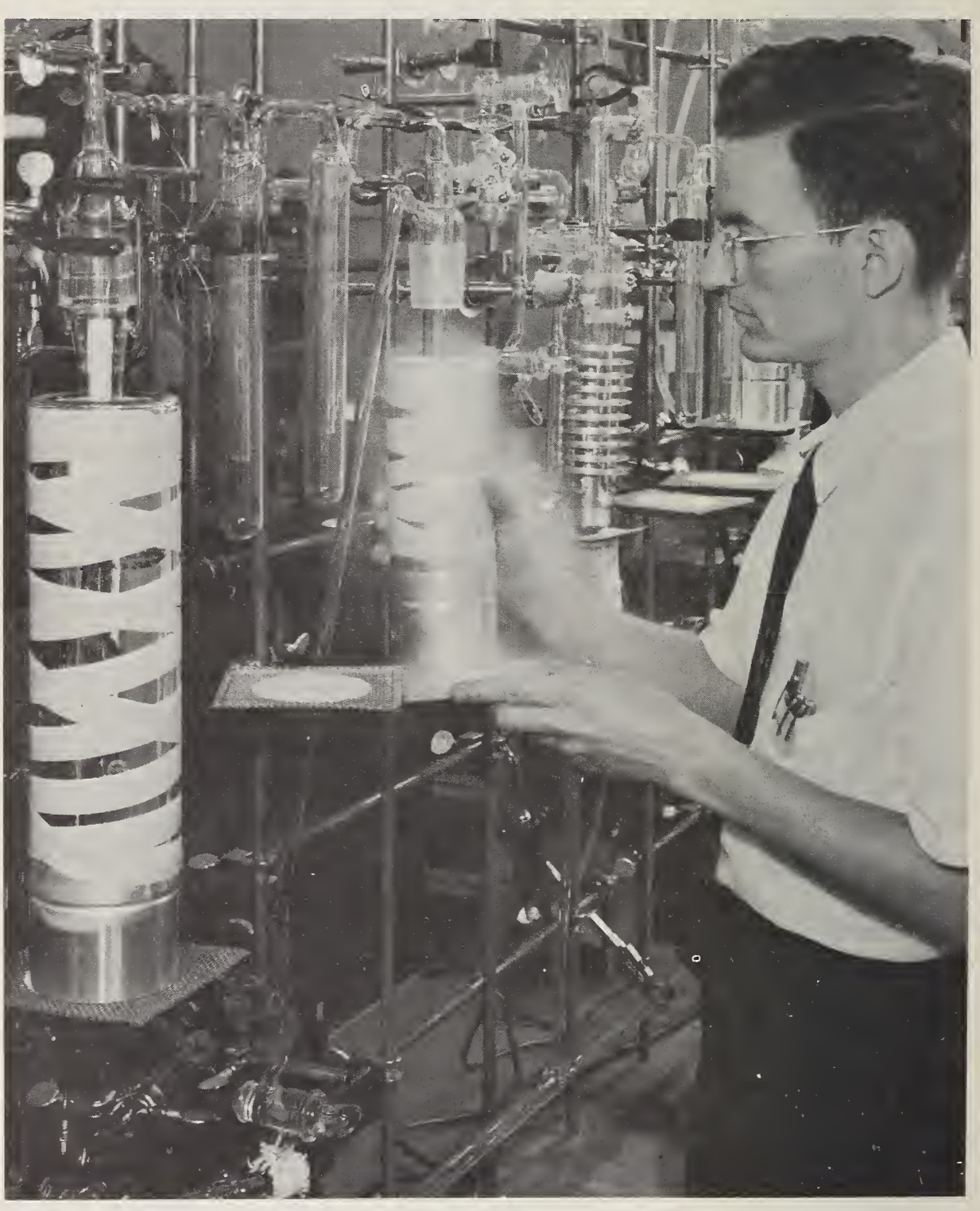
International Comparison of Techniques for Determining Purity. Impurities in almost all chemical substances cause depression of the freezing point. Measurement of this depression provides one of the most widely accepted methods of determining the absolute purity of chemical substances. Since workers in different laboratories and different countries have obtained varied results, the best conditions for the determination and the use of data are not universally known.

At the request of the International Union of Pure and Applied Chemistry, the Bureau has organized a cooperative program on purity control. This program features a comparison of analyses by the most experienced international laboratories. The Bureau has issued to these laboratories four cryoscopic samples of benzene, namely, one sample in highly pure form and three contaminated with regulated amounts of known impurities. The pure benzene was refined to a higher purity than has previously been achieved on such a large scale—99.999 mole percent. The compositions of these solutions are known only to an otherwise nonparticipating group.

In addition to contributing the samples and participating as one of the research laboratories in the measurement of purity (using calorimetric and thermometric cryoscopic procedures), the Bureau is compiling the data from all the groups. Results from this broad program should provide information on the agreement that can be reached by different laboratories using various cryoscopic techniques to assay the purity of similar systems.

Purification of a Special Lot of Mercury. Although mercury is neither abundantly nor widely distributed in nature, it has played an important role in alchemy, medicine, and modern science through the ages. One

of mercury's important physical properties is its density, which has not been accurately determined. To aid in the determination of this physical property the Bureau subjected 1,000 lb of the virgin metal to careful refining, including acid washing to remove all base metals. The entire purified product was double distilled and then mixed to a uniform substance in a single container. About 40 lb was sent to the National Physical Laboratory at Teddington, England, for a determination of its density. The rest will be used for special scientific research requiring very pure mercury with an accurately determined density.



Apparatus used in studying the photochemical decomposition of organic and inorganic compounds which play important roles in air pollution (page 49).

Reagent Chemicals. Participation in the preparation of specifications and test methods for reagents represents an important area of the Bureau's cooperative activities. By the continual testing of the reagent chemicals which it buys, the Bureau has long assured its laboratories of high-quality analytical reagents—thus maintaining uniform chemical tools for research. Within the area of reagents, it is also active in a committee, established by the American Chemical Society, to investigate the purity of reagent chemicals and to prepare specifications for these materials. This committee is composed of representatives from government, industry, and reagent manufacturers.

A revised edition of new and improved specifications adopted by this group will be published in 1960. Translation of previous specifications by a chemist in Spain has made them available to the Latin countries.

Calibrated Glass Spheres. Requirements of practically every commercial powdered or granular material—from cosmetic face powder to solid adsorbents used in sugar refining—include maximum and/or minimum limits of the particle sizes. In particular, knowledge of particle-size distribution is often required both for quality control and research purposes. Such widely diverse industries as foundries, petroleum laboratories, sugar refineries, soap manufacturers, cement makers and users, roof-material companies and chemical firms use sieves both for checking particle size and for measuring particle-size distribution.

In the past, discrepancies were often found when sieve analyses from different laboratories were compared. One cause of this problem has been traced to the method of calibrating testing sieves, which involves the optical measurement of a small number of openings from which the average sieve opening is computed. If the meshes of the sieve are distorted, causing a wide variety in the shape and size of the openings, particles which are slightly larger than the average opening may find an oversized hole and pass through the sieve. Thus the effective opening will be slightly larger than the average opening.

To eliminate this difficulty, an improved method of calibrating testing sieves—based on the effective opening—was developed. This technique involves using a set of calibrated glass spheres of known particle-size distribution and measuring the diameter of the spheres that will just pass through the sieves. A limited number of calibrated samples were used successfully by various industries in the past eight years. Because of the increasing demand for the samples, two new lots were recently prepared for distribution as NBS standard samples. With these standards, closer tolerances may be achieved in the testing of commercial sieves and more reproducible results obtained in sieve analysis.

Uranium Isotopic Standards. In cooperation with the Atomic Energy Commission, a series of 15 isotopic standards of uranium oxide has been prepared for evaluating reactor fuels and for applying in related branches of nuclear chemistry. These standards are available to both domestic and foreign laboratories through the usual AEC licensing arrangements. An

The standard sample for sieve calibration is a set of calibrated glass spheres of known particle-size distribution (inset). In use, the sample is placed in a graduated nest of sieves and is then agitated. The beads remaining in each sieve are indicative of the size of its openings. This method has proved superior to the optical observations formerly used in sieve calibration (page 53).

NBS standard sample of highly purified normal uranium oxide (U_3O_8) is also being distributed for the chemical standardization of uranium analyses.

Spectrometric Analysis by X-rays. The determination of composition by X-ray spectra has the advantages of providing improved precision for major constituents and being nondestructive to the samples. The X-ray method can be applied to the analysis of samples in various forms, including solid sections of metals, compressed pellets of powdered materials, and even liquid samples or solutions with the aid of a spectral cell.

Recent improvements in equipment for the analysis of materials by X-ray spectra enable this tool to be employed with greater speed and efficiency. A multichannel X-ray unit has been installed which provides simultaneous measurement of the concentrations of 10 chemical elements. These may be selected from a group of 15 elements each on a fixed wavelength channel. In addition, a scanning unit permits the selection and measurement of an element not included in the fixed array. This unit has been calibrated for the analysis of iron and iron alloys over a wide range of compositions, covering low-alloy steels, stainless steels, and tool steels. It will be employed largely to measure the uniformity of metals and alloys used for calibrating optical and X-ray spectrometers in other laboratories. These instruments are designed for controlling composition by the iron and steel industry and for analyzing the finished products by both the producer and the consumer.

Nuclear Magnetic Resonance Studies. The techniques of magnetic resonance spectroscopy provide the chemist with an exceedingly valuable tool for investigating molecular structure, chemical equilibria, analytical problems, and kinetic processes. The superior resolution achieved in the spectral range of nuclear-resonance absorption has enabled the study of fine

details in molecular structure and interactions entirely inaccessible by other methods. These applications are possible because of the extreme sensitivity of nuclear magnetic resonance to the nature of the molecular environment.

During the year the Bureau initiated a new project on the measurement of nuclear spectra of selected chemical compounds under conditions of high resolution. The basic apparatus consists of a high-resolution electromagnet (having a nominal field of 14,000 gauss) and three radiofrequency transmitter-receivers operating at three frequencies. Initial studies emphasize the structural chemistry of compounds containing phosphorus, fluorine, and carbon, and molecular processes involving proton exchange.

2.6. Mechanics

Precise mechanical measurements are critically needed in research, development, and production of many items. The accuracy required of these measurements has increased to the point where more adequate transfer instruments and improved calibration standards are needed, particularly in such areas as propulsion, guidance systems, and airframes for aircraft, missiles, and space probes.

In its mechanics program, the Bureau develops and maintains standards of force, pressure, mass, shock and vibration, sound intensity, and the rate of gas and liquid flow. It also develops measurement techniques and transfer standards so that these standards can be disseminated to science and industry. Bureau work also includes determining the density of solids and liquids; the velocity of sound in gases, liquids, and solids; the constant of gravitational force; and the properties of materials and structures.

These standards are in growing need over ranges that are extending upward and downward. Pressure measurement, for example, is now needed in the range of 100,000 atmospheres, where industrial processes now operate. On the other hand, high-altitude and high-vacuum studies have increased the need for extremely low-pressure measurement. Requirements for force measurements have increased with the rapid development of propulsion systems having thrusts exceeding 1,000,000 lb.

During the past year, progress was made in standards of high-pressure and humidity; measurements of dynamic pressure; high-temperature strain gages; and in the design of dead weight machines for the calibration of force-measuring devices. Yet, still more effort will be needed in these and other areas of mechanical measurement if the needs of science and technology are to be met adequately.

Expanded Pressure-Calibration Service. Attention was given to the urgent problem of providing calibration services over a much larger range of pressures than now covered (presently 5 to 60,000 psi). Plans are being made to establish additional fixed points at pressures to several hundred thousand pounds per square inch, and equipment was built for gathering information on the behavior of materials at pressures up to 1,500,000 psi. In calibrating instruments for measuring high-transient pressures, a unique

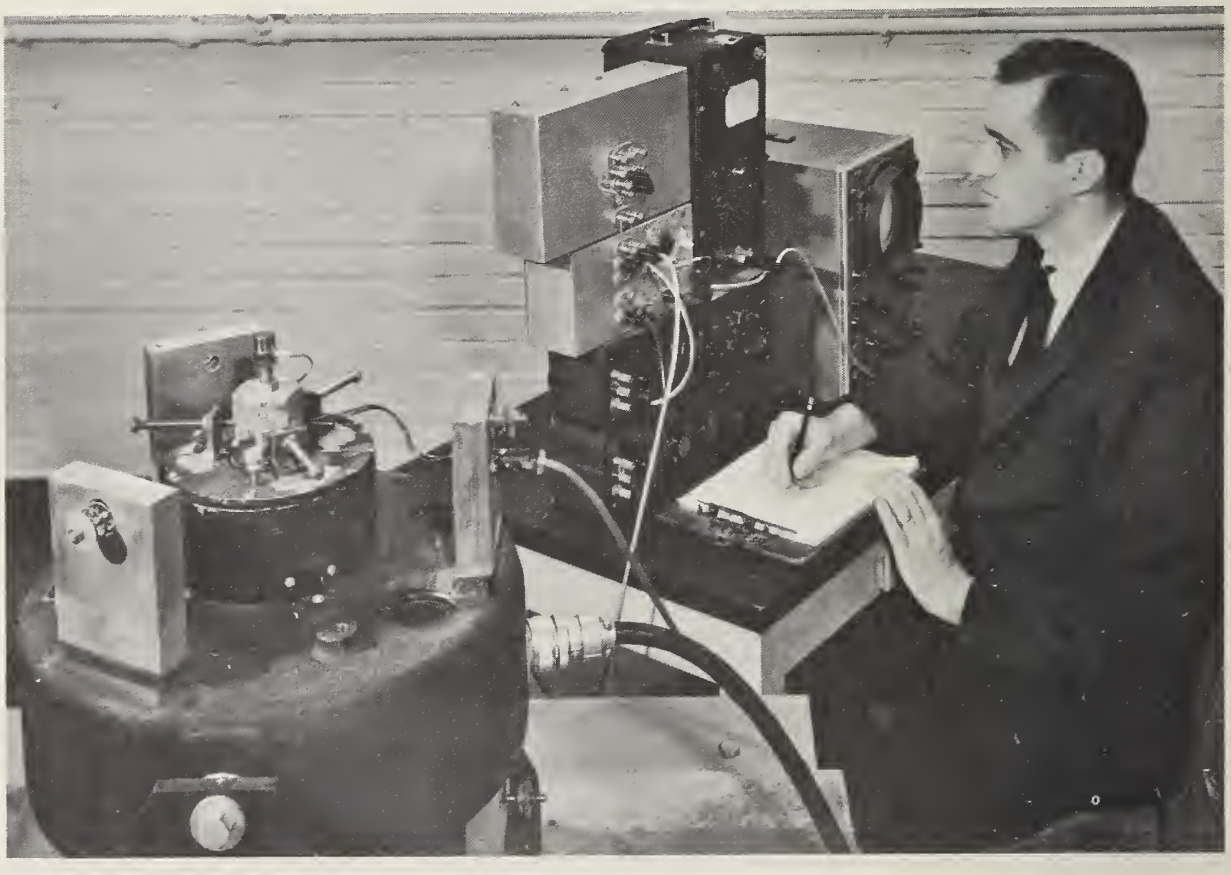
device was constructed to generate pressure in steps of accurately known amplitudes up to 50,000 psi.

Because of the increasing requirements for accurate measurements of low pressures, plans were made for substantial work toward improving methods for measuring pressures in the vacuum range.

Vibration Pickup Calibration Service. Vibration measurements are needed in developing space vehicles, missiles, aircraft, ships, and machines. There is a continuing demand for improving the accuracy of these measurements, which are based on vibration standards.

As part of a program of developing vibration standards, an electrodynamic standard was modified so that it is free of transverse motion throughout almost all of its frequency range. The standard produces rectilinear motion by a suspension of its moving parts from a frame by tensioned wires. The standard (an electrodynamic vibration exciter equipped with a velocity-sensing coil) is calibrated by the reciprocity method. In the vibration pickup calibration service recently established at the Bureau, the standard is used at frequencies from 10 to 2,000 cps at accelerations up to 10 g. The errors of the motion applied to the pickups do not exceed 1 percent up to 900 cps and 2 percent between 900 and 2,000 cps.

Stroboscopic Vibration Analyzer Devised. Stroboscopic instruments have been used for many years to visualize and analyze periodic motion. Applying such instruments to large, complex structures is limited because it is not possible to observe all parts of a structure at the same time. At higher frequencies, amplitudes of motion are too small to be seen. These



Vibration pickup mounted on the newly modified vibration standard (left). At each of the 3 rectangular blocks, helical coil springs are attached to wires to minimize transverse motion during vibration (page 56).

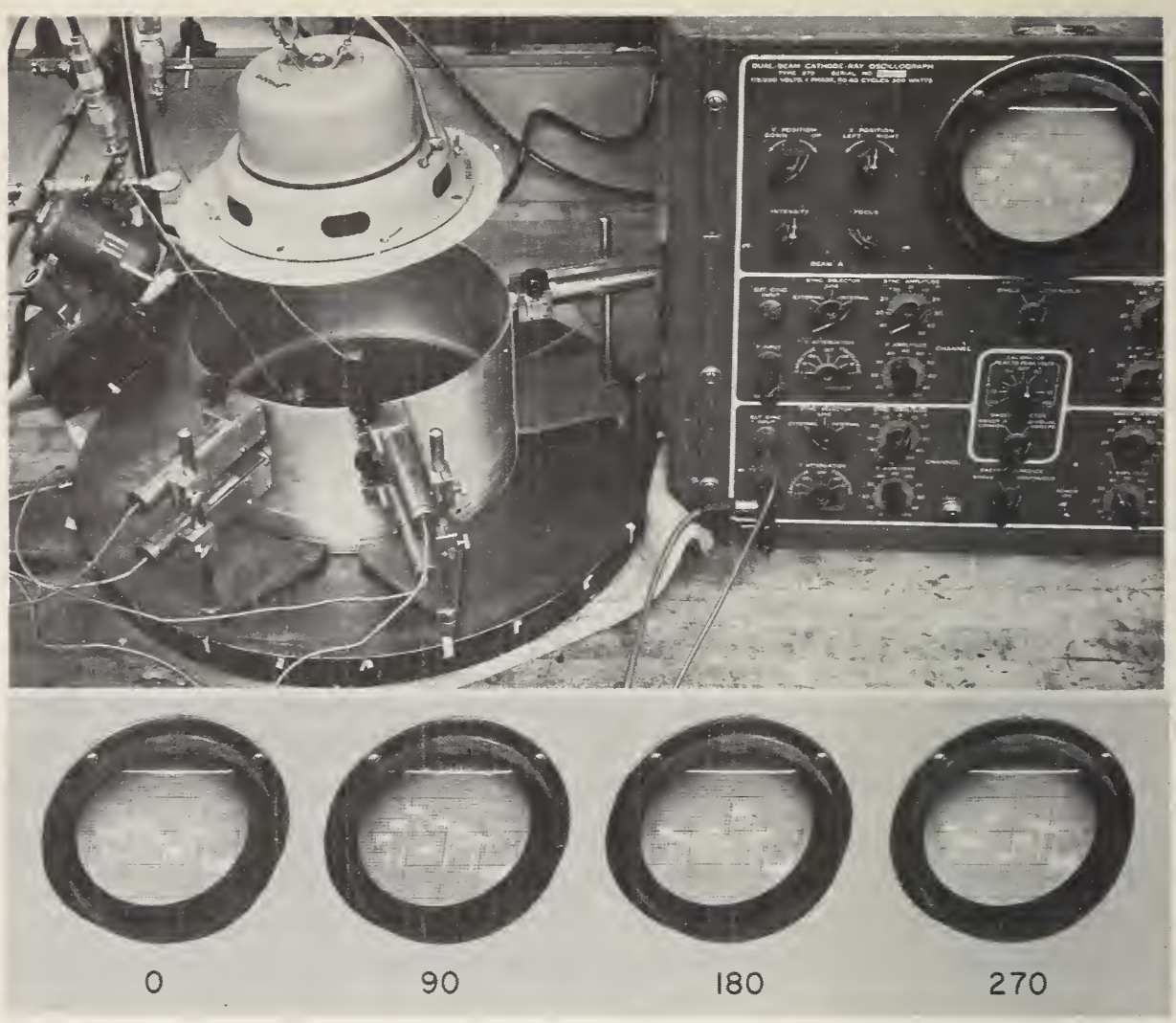
difficulties were resolved by an instrument for studying amplitude and phase relations in complex periodic phenomena, principally vibration of complicated bodies. The motion at each point of interest is detected by a vibration pickup. The signal from each pickup is heterodyned with a common signal that differs from the vibration frequency by a small amount to produce a set of signals at the difference frequency. The desired relations are exhibited at the difference frequency that is low enough to give a slow motion effect. The output circuits allow a choice of presentation suited to a particular problem.

Vibration Dampers Evaluated. In a program for the Rural Electrification Administration, Bureau scientists recently performed field vibration tests on telephone wires installed near Tyler, Minn. These tests were made to evaluate various dampers installed on telephone wires used over extra long spans. Plastic sleeve dampers had been found effective on spans up to several hundred feet long. These dampers were found ineffective, however, where there are many spans between 800 and 1,900 feet, and where prevailing winds are from 10 to 30 mph. Under these severe vibration conditions, there were frequent fatigue failures of the wire at connectors and splices. Although field tests indicated that most types were ineffective, two types were satisfactory, including one of Bureau design. The Bureau's damper consists of a hollow tube filled with sponge rubber under slight compression, providing a continuous resisting force to all high-frequency vibrations.

New Acoustical Theory Proposed. Sound reception by the ear was described mechanistically in a new theory that is useful for calculating, in a simple way, the quantitative limits of the ear's operation as part of a communication system. The theory was derived from consideration of efficiency limits of instruments used in measuring rapidly fluctuating sounds. Results of experiments dealing with just noticeable differences in frequency and energy of sounds, detectable by the human ear, were used to compute two constants needed in the theory. These constants are useful in describing several aspects of ear behavior.

Uniform Magnetic Field Equipment Built. A standard is needed for measuring the susceptibility of hearing aids to annoying hum that is generated by alternating fields such as those surrounding fluorescent lights, motors, and other equipment. In developing methods for the Veterans' Administration to test hearing aids for hum pickup, equipment was built to produce a nearly uniform magnetic field. The equipment consists of three mutually perpendicular coils; each coil can produce a nearly uniform field over a cross-sectional area approximating the maximum area of a typical hearing aid. A feedback system was also developed to cancel the ambient stray fields without affecting the test field.

Improved Hygrometers Developed. To provide a basic reference for humidity measurements, a gravimetric hygrometer was built to permit direct weighing of the water contained in a known gas volume. This instrument should make it possible to attain needed improvement in the accuracy of



A stroboscopic vibration analyzer was developed for determining amplitude and phase relations of vibrations of any frequency. This device is expected to be useful in determining vibration characteristics of aircraft and missile structures. Inset represents vibration patterns (page 56).

humidity measurements, particularly at temperatures below the freezing point, as involved in atmospheric studies.

Further attention was given to improving humidity-measuring elements for use in radiosondes, and a very promising improvement (a thin barium fluoride film element) was developed under the sponsorship of the Navy Bureau of Aeronautics.

Fuel Flowrate Calibration Facilities. For optimum flight performance, aircraft engines and their fuel metering components require precise adjustment and test prior to installation. Such tests require the measurement of fuel flowrates to a precision of 0.5 percent or better. Under sponsorship of the Navy Bureau of Aeronautics, the Bureau maintains reference flowrate calibration facilities for use with liquid hydrocarbon fuels. These facilities are used to calibrate transfer reference flowmeters whereby the accuracy of calibrators at other locations can be compared. Manufacturers of flowmeters, aircraft engine accessories, aircraft engines, and airplanes, as well as the military services are all participating in this program of flowrate standardization. Throughout the aircraft industry, there have been closer correlations between tests of identical components at different locations, thereby improving the flight performance of engines.

This program also includes evaluating flowmeters for use in aircraft test

work. Evaluation tests reveal the limitations of existing flowmeters, show the modifications required for better performance, and encourage the development of new instrumentation for precisely measuring flowrates.

Inertial Forces in Unsteady Flow Studied. When a fluid is accelerated past a submerged object, the total force exerted by the motion on the body can be considered to consist of a drag force (caused primarily by flow separation) and an inertial force that accompanies the acceleration of the fluid. A study of this problem was sponsored by the Office of Naval Research, primarily to obtain instantaneous force coefficients for bodies such as cylinders and flat plates for the general case of unsteady flow of water. Of particular interest to hydraulic engineers is the force of waves on components of coastal structures. In problems of this nature, models are often studied. The need to know the scale effect on each force component is one example of the need for a basic understanding of the problem. The force components depend upon the entire flow around the object, including the wake and motions aft of the body. For this reason, research is now directed toward the relation between the instantaneous force, as flow velocity changes, and the instantaneous shape and motion of the wake.

Internal Progressive Waves Investigated. Just as waves form on a water surface, so wave motions may also occur between denser and lighter layers of water when, for example, these layers are formed by solar heating. Wave motions in such layers are less well understood than ordinary surface waves, and their behavior depends on the amount and sharpness of the density difference. An investigation, sponsored by the Office of Naval Research, is being conducted to determine the formation and characteristics of such waves.

Stratified conditions were simulated in the laboratory by placing a layer of fresh water on a layer of salt water in a long rectangular channel. Waves nearly as high as the layer of smaller thickness can be produced with scarcely a perceptible disturbance at the water surface. Such waves travel much slower than surface waves. Their height, velocity, and decay with distance as a function of the density variations are the chief characteristics being investigated.

Instability of Laminar Flow Examined. Because laminar flow is unstable in a boundary layer (a thin layer near a wall), turbulent motions ensue and flow characteristics are completely altered. How turbulent motions begin from an instability is a subject that has been under intensive investigation for some time. The National Aeronautics and Space Administration is continuing sponsorship of this investigation at the Bureau. Present theories accurately describe the better known unstable wave motions that lead to secondary motions in the form of streamwise vortices. These motions bridge the gap between wave and turbulence, thus they are a vital link in the onset of turbulent motion. They are not yet, however, embodied in existing theories. A true physical picture is emerging from this work, and the information is enabling the theorist to formulate a realistic theory of the origin of turbulence.

Dynamic Properties of Materials Measured. There is a lack of reliable and comprehensive data on the effects of dynamic loading on the physical properties of structural materials. Thus, engineers have been handicapped in designing structures to resist loads that are applied rapidly. For some important structural materials, it has been shown that the values of physical constants determined under static loading are significantly different from values determined under rapid loading.

To meet these needs, the Bureau has been investigating new devices and techniques for measuring large transient strains in long bars. The dynamic mechanical properties of specific structural materials were also measured.

Further insight is provided on the theory of stress wave propagation in solids by investigating stress wave pickups operating on resistance, capacitance, and inductance principles. These results are being used in attempts to obtain reliable stress-strain relations for structural materials.

Strain Gage Evaluation Facility. To assure safe design and efficient use of structural materials in modern applications, it is essential to have a knowledge of the properties of materials and structural configurations at elevated temperatures. To determine these properties accurately, it is necessary to measure the strains and deformations in materials under load at elevated temperatures.

A number of gages have been produced to meet the increasing demand for high-temperature strain-measuring equipment. Experience with these early gages indicated that the problems associated with their use were more complex than had been generally anticipated and that the test results obtained with them were often of doubtful validity. It was soon apparent that a comprehensive evaluation of these gages was required, and the Departments of the Navy and Air Force undertook the sponsorship of an evaluation facility at the Bureau.

The Bureau has developed facilities for determining some of the important characteristics of these gages. The factors measured include gage factor and its variation with temperature; change of resistance with time at constant temperature; change of resistance with temperature; behavior when heated rapidly; performance when subjected to high strain levels; and, the effects of storage at various humidity levels. A number of gage types have been evaluated. The development of improved evaluation techniques and facilities as well as the evaluation of available gage types is continuing (for other Bureau strain-gage work, see p. 84).

Thermocouple Reference Being Determined. There is need for a temperature-sensing device that will withstand temperatures of 3,500° F and above. The iridium versus iridium-rhodium thermocouple has gained in popularity with researchers and developers, in the jet-engine industry, and to some extent in the rocket and reactor fields. A serious drawback to the use of this thermocouple is the lack of a reference table, similar to those now used for conventional thermocouples.

In previous work with this thermocouple, errors came from three sources:

An engineer with the Department of Weights and Measures, National Laboratory of Metrology, Mexico, is instructed in the operation of a large precision balance used for weights up to 25 kg. During the year, approximately 900 foreign scientists and technicians, representing 50 countries, visited the Bureau (page 13).

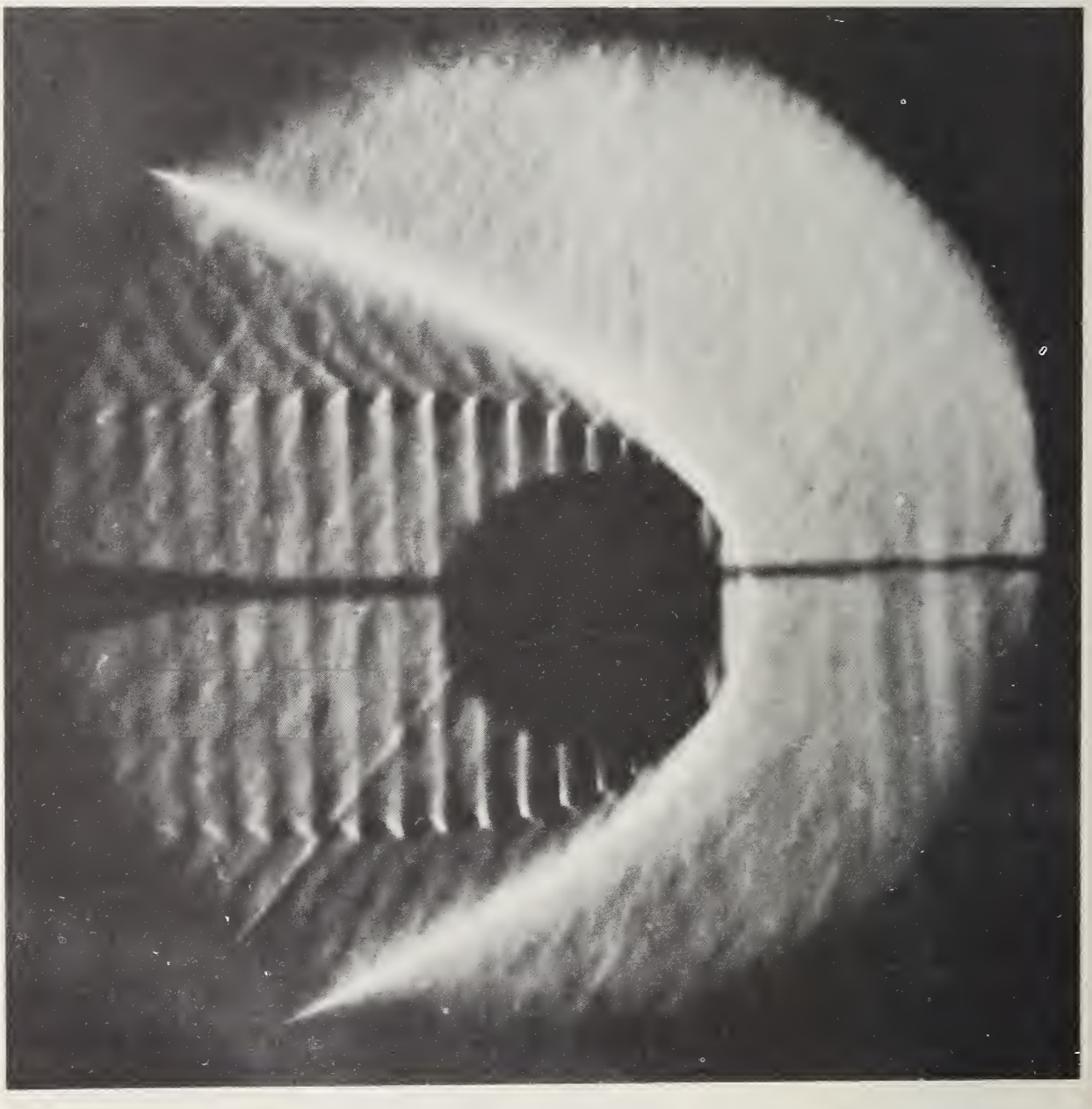
Black smoke came from oxidation of the thermocouple and blackbody, excess heat was conducted from the blackbody, and stray fields were introduced by the high-frequency generator used to heat the blackbody. To minimize these errors, changes were made to the equipment. Smoke was eliminated, and heat conduction and stray fields were nearly eliminated. Preliminary tables were determined (to 3,800° F) for 2 thermocouples of iridium versus iridium plus 60 percent rhodium. Other thermocouple work is described on page 291.

Jet-Engine Thermocouples Tested. A continuing program directed toward improving equipment for measuring temperatures in jet engines, is sponsored by the Wright Air Development Center. This work is concerned with maintaining accuracy and dependability of sensing and measuring elements as conditions in the engines become more severe.

A new type thermocouple, designed to measure preturbine temperatures up to 2,300° F, was developed by an industrial contractor for the sponsor.

The Bureau began determining a reference table for this thermocouple, and tentative values were obtained. A thermocouple indicator was examined for use in air varying from tropical to arctic temperatures. Because of changes made as a result of this examination, the instrument is practically unaffected by changes in ambient temperature.

Several cooperative projects were begun between industrial laboratories and the Bureau at the request of the Committee on Physical Measurement Sensing of the Society of Automotive Engineers. Changes in two groups of engine-type thermocouples were determined after exposure to jet engine exhaust gases for 1,000 hours at 1,250° and 1,750° F. The thermocouples were not mechanically affected at the lower temperature, but in most cases they were destroyed at the higher temperature. At the higher temperature, most thermocouples were oxidized; the ones which were not destroyed by oxidation continued to function. In neither case, however, was the signal



To learn more about jet engine combustion, the shock waves of high-speed missiles were used to study combustion in supersonic streams. Here unsteady combustion is displayed behind the shock wave of a sphere propelled at Mach 5 through a mixture of hydrogen and air (page 63).

from the functioning thermocouple affected seriously. Observations have been made which show that the response time of a thermocouple changes with temperatures, and these data are being analyzed.

Jet-Engine Combustion Explored. Combustion in standing detonation waves and in supersonic streams appears to be of great practical importance in the field of propulsion of hypersonic missiles and planes, but only limited information is available on the requirements for combustion under such conditions. One method of research is to use the shock wave in front of high-speed missiles to investigate conditions such as pressure, temperature, and shock strength needed for combustion in a standing detonation wave. This method can also be used to study the use of a solid object to stabilize the detonation wave in space. Spheres of up to 20-mm diameter were propelled to Mach 10 in equipment that was assembled to make optical studies of gas near these spheres. Exploratory experiments (up to Mach 6 in stoichiometric mixtures of air and hydrogen at low pressure) indicated that combusion is initiated by the shock, but that it occurs behind the sphere and its shock wave.

Another jet-engine problem is the high-altitude effect that leads to low combustion efficiency and capacity of the combustion chambers. It was found that small quantities of oxygen in the primary zone of a combustor increase both the efficiency and capacity of combustion at a given altitude, or enable an engine to maintain performance at higher altitudes.

2.7. Organic and Fibrous Materials

The Bureau's research in organic and fibrous materials spans the broad field of natural and synthetic polymeric materials. To gain a better understanding of the association of constitution, structure, and properties of polymers, studies are being conducted on rubbers, textiles, papers, leathers, plastics, dental resins, and related materials. The properties of polymers depend upon the size, shape, distribution, and flexibility of their molecules, and interactions with other molecules. Basic knowledge of the polymers and improved methods for measuring their fundamental properties are necessary for the development and efficient utilization of these materials.

Basic research during the year covered reaction mechanisms involved in the degradation of synthetic resins and collagen exposed to high temperatures and to nuclear radiation, crystallization phenomena in polymers, polymer-polymer, and polymer-solvent interactions in polymer solutions, and glass transitions in rubber-sulfur systems. New methods were developed for determining water penetration in untreated and polymer-impregnated leathers, surface tension of high viscosity liquids, fluorescence of dental materials, and for the interlaboratory comparison of testing procedures. Investigations on the properties of materials dealt with creep of plastics, power-loss of tires, static-electrical effects on textile fabrics, compressive properties of tooth enamel and dentin, and dimensional stability and detail reproduction of elastomeric dental impression materials.

Degradation of Collagen. To provide basic information on the properties of leather, the Bureau is investigating the processes that occur in the degradation of collagen, the white connective tissue of hides from which leather is made. Collagen is a complex protein containing 17 amino acids. The tensile strength, elasticity, toughness, and pliability of leather are attributed to the fibrous matrix and molecular structure of this natural polymer. However, under certain environmental conditions these properties change and the leather deteriorates. These factors are of prime concern to tanners, leather manufacturers, and industrial users of leathers.

Degradation of collagen, which is caused by heat- and gamma-radiation, was studied in steer-hide powder and kangaroo-tail tendon. For the tests, the specific amino acids affected were determined, the solubility and shrinkage temperature observed, and the water-vapor absorption and ultraviolet and infrared absorption measured. Those amino acids which have sulfur and hydroxyl in their side chains (such as methionine, serine, threonine, and tyrosine) were found to be most susceptible to both heat and gamma radiation; alanine, glycine, hydroxyproline, proline, and arginine were least affected.

Little damage to amino-acid structure was noted at radiation doses of less than 20 megarads. Heat degradation but not radiation degradation was accelerated by oxygen and moisture. On the infrared spectra of the most severely heat-degraded materials, some small change was noted in the spectral region of 7 to 9 microns. High ultraviolet absorbence by the water-soluble fractions of the irradiated material is attributed to formation of specific complex absorbing groups.

Water Penetration Test for Sole Leather. Dynamic testing equipment has been developed to measure the resistance of sole leather to water penetration. The apparatus for this test automatically flexes the leather specimen, with one side exposed to water, until penetration occurs. Flexing greatly accelerates the rates of penetration and absorption of water as compared to rates under static conditions.

Factors that influence penetration and absorption under the dynamic conditions are thickness of the specimen, location on the sole leather bend, compression of the specimen, tannage, and impregnating materials. Chrome-retanned crust leather showed higher resistance to water penetration than vegetable-tanned crust leather, but both types of leather were considerably less resistant than finished vegetable-tanned leather.

Impregnating the vegetable-tanned crust with polymers increased the resistance to water penetration and water absorption 20-fold. Thus, the dynamic water-penetration test will be useful in developing impregnants to improve water repellancy in sole leather.

Power Loss and Operating Temperature of Tires. The high-speed highway has accentuated the importance of power loss and operating tem perature in tires. To study this problem the Bureau has measured overall power loss by using two dynamometers—one to measure the power input and the other to measure the power output from the tire. In the investiga-

tion, it was found that tire construction and type of rubber are predominant factors influencing the power loss and operating temperature. These factors determine the manner in which power loss changes with speed, load, and inflation pressure. The inclusion of natural and synthetic rubber in the same tire has an adverse effect on power loss.

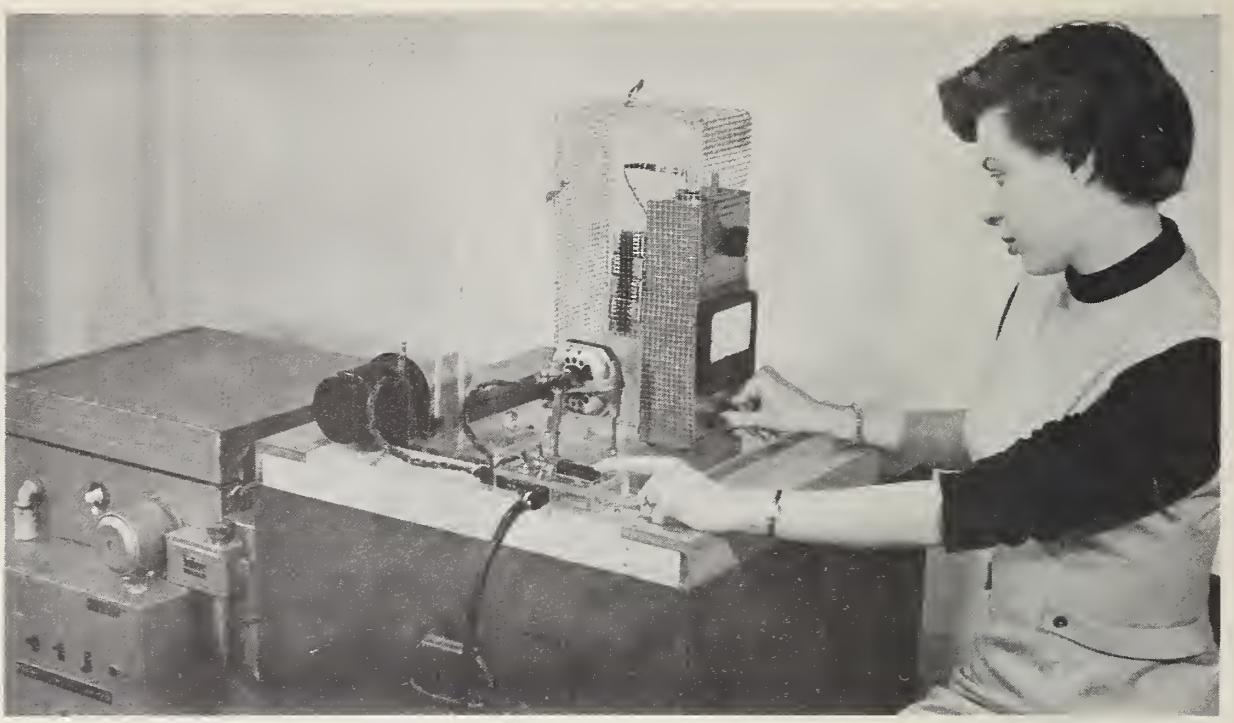
The operating temperature was found to be a function of the power loss, rate of heat transfer within the tire, and rate of heat transfer from the tire to the environment (road and air). At high speed, the first two factors govern the tire temperature.

Glass Transitions in the Rubber-Sulfur System. The volume-temperature relations for mixtures and vulcanizates of rubber and sulfur have been measured by using an automatic recording interferometer. The results, covering a temperature range from −180° to +150° C and a composition range from 0 to 30 percent bound sulfur, supplement earlier Bureau data. In each case a discontinuity in slope is observed at a characteristic temperature, the glass transition point, below which the material loses its rubberlike properties and becomes a hard rubber. A linear relation is noted in each case above the glass transition temperature; below this temperature the slope decreases with diminishing temperature. The glass transition temperature of the mixtures is independent of sulfur composition. However, the transition temperature for the vulcanizates increases with rising sulfur content along a sigmoid curve from −69° to +90° C.

Interlaboratory Studies of Test Methods. Two problems of present concern to industry are: How to determine which of two test methods gives the more sensitive and precise results; and how to explain the lack of agreement in results obtained by different laboratories which use the same test method. A new mathematical theory underlying the comparison of results from different laboratories is being applied by the Bureau to interlaboratory comparison of test methods (see also 2.11, p. 95).

When the average value obtained by any particular laboratory for a given material is plotted against the average obtained by all the participating laboratories, the points corresponding to the various materials are found to lie approximately on a straight line; hence the theory has been given the name "linear model." An interlaboratory study based on this model makes it possible to describe and assess the relative importance of the different sources of availability and to determine how many replicate measurements are needed. The linear model has been applied successfully to studies of three important methods in the pulp and paper industry—tensile strength, airleak smoothness, and determination of pentosans—and to the development of a tentative standard reference paper for calibrating the internal tearing strength method.

Electrical Resistivity of Fabrics. The comfort and appearance of clothing when worn under cool, dry conditions is appreciably affected by static electricity. However, uncomfortable effects can be alleviated by applying textile finishes which reduce the fabric's surface electrical resistivity.



The tendency of many fabrics to accumulate static electricity affects their comfort, appearance, and other qualities. This apparatus is used in evaluating treatments used to counteract the static effect (page 65).

To evaluate the effectiveness of these finishes, equipment was constructed, in cooperation with the Army Quartermaster Corps, for measuring the resistivity of fabric samples. For experiments, temperature could be varied between $-60°$ and $+120°$ F and relative humidity, between 4 and 98 percent.

Results indicate that surface resistivities less than 10^{12} ohms/square are desirable for satisfactory antistatic behavior. Only a few of the antistatic finishes tested were effective at low-relative humidities. Cotton has a resistivity of 10^{10} ohms at 50 percent relative humidity and 70° F and thus requires no treatment for use in this environment; however, it exhibits pronounced electrostatic effects under lower temperature and humidity conditions. The surface resistivities of cotton, nylon, and wool fabrics were all greater than 10^{15} ohms in dry air at 32° F.

Surface Tension of High-Viscosity Liquids. As part of an investigation of the mechanism of reinforcement in glass-fiber-reinforced plastics sponsored by the Navy Bureau of Aeronautics, a versatile instrument was developed to measure surface tension of high-viscosity liquids. For the apparatus, a tensiometric technique utilizing a strain-gage-type testing machine was modified by adding a platinum-iridium ring. This ring enables full-scale readings with only a 2-gram load.

With this technique the load on the ring as a function of the ring displacement is continuously recorded, and the effect of the ring-displacement rate on the maximum loads (i.e., the surface tension), can be determined. Beside its use in the rapid, routine determination of the surface tensions, the method provides a simple technique for characterizing the physical properties of liquid surface films and for studying the effects of a number of independent variables on such films.

Creep of Transparent Plastics. Plastic windshields and canopies of highspeed aircraft may undergo serious creep deformation at high temperatures colated by aerodynamic heating. Under sponsorship of the Navy Bureau of Aeronautics, the creep behavior of transparent plastics exposed to temperature conditions simulating those encountered by aircraft windshields and canopies has been investigated. The heat conditions applied to the plastics include uniform temperature, temperature gradients, and shock heating. The temperature gradient corresponds to the condition encountered in level flight of an aircraft and the shock heating simulates thermal conditions during a dive of an aircraft. Results indicate that plastics withstand higher surface temperatures without serious creep deformations when exposed to temperature gradients and to shock heating than when exposed to uniform temperatures.

Radiation-Resistant Polymers. Radiating a polymeric substance may cause several types of chemical change, depending on molecular structure. Chains may be either broken or crosslinked, or some of the branched atoms may become detached to form small volatile molecules. In addition, relatively large amounts of unstable or reactive species (free radicals) are produced, some of which have unusually long lifetimes because of the slow diffusion of long polymer chains.

Investigations are being conducted for the Air Force on the radiation effects of polymeric stability. A knowledge of the mechanisms and reactions will enable prediction of the effects of such energy on materials and the production of suitable materials. To establish the mechanisms of the chemical reactions initiated by radiation, electron spin resonance is being used to characterize the free radicals produced, a zero strength tester to measure the change in polymer strength after irradiation, and the mass spectrometer to determine the volatile substances produced. Many other techniques are being employed.

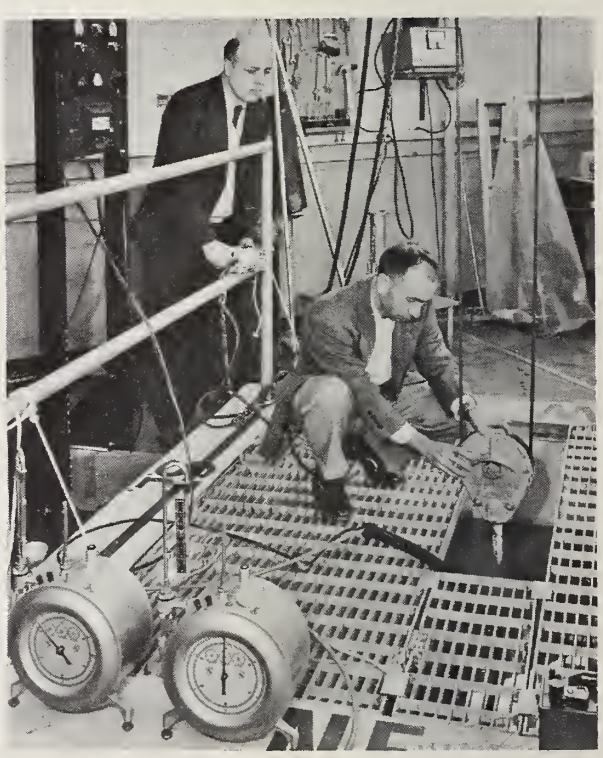
Recently, it was observed that polytetrafluoroethylene degrades at least 100 times more slowly in the absence of air or oxygen. Thus, the polymer may be extremely useful under conditions (such as satellites in the upper air strata) where, although radiation is present, oxygen is avoided.

Crystallization of Crosslinked Polymers. When polymer molecules are intermolecularly crosslinked by either chemical means or by the action of high-energy ionizing radiation, a three-dimensional insoluble network is formed. If the network is composed of chains of sufficient regularity, crystallinity can develop at appropriate temperatures without any deformation. Detailed studies of the melting and crystallizing behavior of such systems have shown that these properties are dependent on the number of crosslinks introduced and on the relative arrangement of the chain units at the time of network formation. For networks formed from chains that are randomly arranged, a substantial depression in the melting temperature is observed with crosslinking. Consequently at a given temperature the rate of crystallization is retarded.

In contrast, for networks formed from ordered chains, as in the case of fibrous natural rubber or of crystalline but nonoriented polyethylene, the melting temperature is only slightly affected by the introduction of crosslinks. Thus the rate of crystallization for ordered chains is not as severely retarded. At temperatures above the melting temperature these networks represent a new type of partially ordered liquids.

Thermal Stability of Polymers. At the request of the Air Force the Bureau has undertaken a research program on the thermal stability of polymers at temperatures up to 1,200° C. The products of pyrolysis were fractionated and analyzed by mass-spectrometric, microcryoscopic, microchemical, and infrared methods. These studies have provided a better understanding of the relationships between thermal stability of polymers, and their chemical composition and molecular structure. For example, vinyl polymers yield volatile products containing from 0 to 100 percent monomer, in proportion to the amount of tertiary and quarternary carbons in the chain. Pyrolyzed polymers that are highly crosslinked or in which crosslinking develops during pyrolysis, yield a carbonaceous residue. In the temperature range 150° to about 500° C, fragmentation of the polymer is due chiefly to the primary effect of heat on the polymer. At higher temperatures there was further break up of the fragments due to the intense heat.

Interactions in Polymer Solutions. The commercial significance of high polymeric substances such as fibers, rubbers, and plastics has resulted in the rapid rise of new and major industries. Essential to the develop-



Research on the synthesis and radiation-resistance of aromatic fluorocarbons is aimed at determining basic principles needed for guidance in the production of solid polymeric materials having increased stability. Polymers are sealed in a special Dewar (left) in order to control the temperature of their environment, and then are exposed to gamma rays from a cobalt-60 source submerged in a pool of water (right) (page 67).

ment and improvement of synthetic polymers is a knowledge of the structure and behavior of the macromolecules in solution and in the solid state.

When polystyrene is dissolved in cyclohexane near room temperature, the polymer-polymer interactions are nearly equal to the polymer-solvent interactions. In an investigation of such solutions, the exact temperature (theta) when these interactions are equal was found to vary considerably, depending on the nature of the end groups and the length of the polystyrene molecule. The temperature dependence of the refractive index increment of polystyrene in cyclohexane and toluene solutions was accurately determined and was found to agree with results calculated by other methods.

Physical Properties of Tooth Enamel and Dentin. Few data are available on the physical properties of tooth enamel and dentin because of the difficulty in preparing and measuring the very small specimens involved. In a project sponsored by the American Dental Association, and the Federal dental services, methods have been developed for preparing small cylindrical specimens of tooth structure and measuring their stress-strain properties in compression.

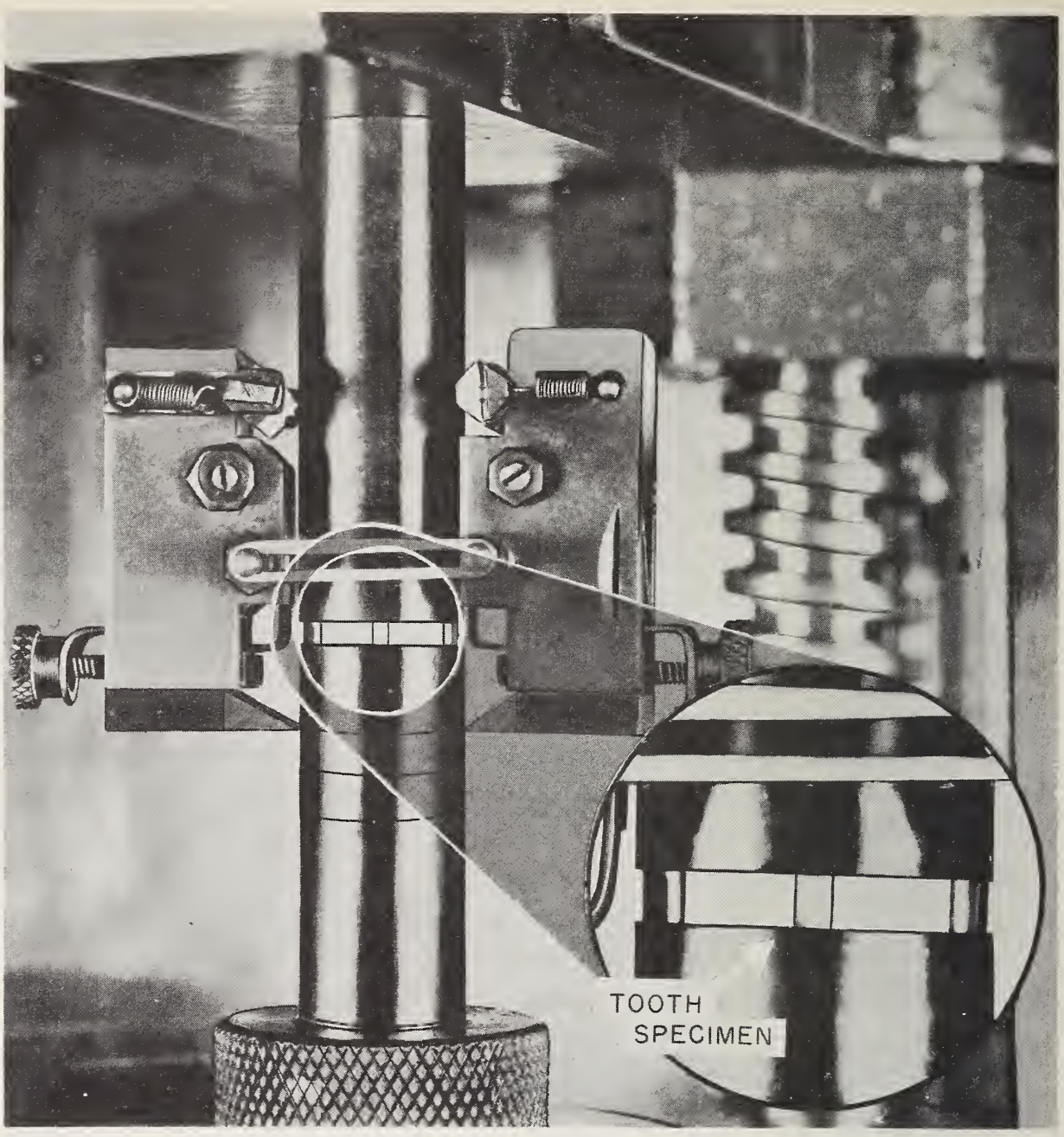
The specimens of enamel and dentin were shaped with a diamond instrument in a dental hydraulic handpiece. Properties varied rather widely, depending on the specimen's original location in the tooth and, for enamel, the orientation of the specimen. Highest values for enamel were obtained for the cusp; intermediate values for the tooth sides; and lowest values for the occlusial surface. Dentin had a higher compressive strength but a lower modulus of elasticity than did enamel. Data derived for the study will be used in evaluating dental-filling materials, in designing cavity preparations, and in demonstrating physical changes in teeth.

Elastomeric Dental Impression Materials. Dentists have recently been using synthetic elastomeric materials to make impressions for artificial dentures and gold inlays for restoring teeth. The properties that control accurate reproductions were investigated in cooperation with the dental services of the Armed Forces and Veterans' Administration. Two types of materials—polysulfide polymer base and silicone base—were examined and test procedures were developed for measuring detail reproduction and dimensional stability.

Synthetic elastomeric materials were found to return to original dimensions as well after compression as the hydrocolloidal impression materials which were previously used. In addition, the elastomers have much greater dimensional stability on prolonged exposure to normal room-atmosphere than to agar-agar and alginate base hydrocolloidal materials. For greater accuracy with elastomers, the gypsum cast of the impression should be made immediately after the impression is removed from the mouth.

Dental Fluorometer. Human teeth fluoresce when exposed to ultraviolet radiation. Healthy teeth emit a blue-white light whereas decayed areas on the teeth emit a brownish light or none at all. If the pulp in an injured tooth is dead, then the tooth shows reduced fluorescence.

In cooperation with the Federal dental services and the American Dental



Apparatus used to determine the compressive properties of human enamel and dentin. Data derived from the study will be used in evaluating dental filling materials, in designing cavity preparations, and in demonstrating physical changes in teeth. Inset shows the tiny cylindrical specimen in place between the pistons (page 69).

Association, a fluorometer has been developed which is capable of measuring the fluorescence intensity of teeth and other tissues in the human mouth. The fluorometer consists of a mercury vapor lamp equipped with a filter that passes only ultraviolet radiation in the 3650 A region of the spectrum. This radiation is focused onto the tooth by a special objective. The tooth absorbs the invisible ultraviolet radiation and emits blue-white visible light. This light is collected by an annular lens around the central objective and is focused onto a photomultiplier detector.

Dental X-ray Radiation. As an aid to the dental profession a motion picture showing the dentist how diagnostic X-ray pictures may be taken with a minimum amount of radiation to the patient was produced in cooperation with the American Dental Association. Procedures by which the dentist can check his X-ray equipment for collimation and filtration of the useful beam,

for tube head leakage and for adequate length of the timer cord, are shown. The movie also demonstrates how the dentist can reduce radiation to the patient by the use of high-speed film with the 80,000 X-ray machines currently available in dental offices.

2.8. Metallurgy

Metallurgical research at the Bureau is directed toward a better understanding of the properties of existing metals in order that improved metals and alloys may be developed to meet new requirements or to give better performance. Much of the work is designed to furnish basic information on metals and alloys in terms of their constituent atomic units. The studies also include the effects of treatment, fabrication, and conditions of service on the structure, behavior, and properties of metals, with particular emphasis on metals subjected to high temperatures. Other investigations concern the causes of metal fatigue.

The complex destructive process of corrosion is investigated from several directions. During the past year studies were made of corrosion reactions at the metal surface, the effects of free radicals on metals at low temperatures, and the mechanism of stress corrosion. These and related programs help not only to maintain a vigorous and effective competence in metallurgical science, but to advance metals technology by providing data on the basic properties of matter.

Heat-Resistant Materials. To obtain basic data that will be used in the design of improved heat resistant metals, studies are being made of the solid-state reactions occurring in alloys of chromium, iron, nickel, and molybdenum. Reports are now being prepared on the chromium-nickel phase diagram, the structure of certain intermetallic compounds, and the solid-state reactions in the iron-nickel molybdenum system.

Creep of High-Purity Nickel. An investigation of the creep properties of high-purity nickel, initially as cold-drawn 40 percent reduction in area, showed that resistance to creep at temperatures below 900° F was significantly increased by cold drawing. At temperatures above recrystallization, however, this strengthening effect was eradicated. None of the existing equations was considered suitable to express or predict the creep test results with high accuracy since the structural changes accompanying the creep process have not yet been adequately defined.

Tensile and Yield Strengths of Die Steels. An evaluation was made for the Navy Bureau of Aeronautics of the tensile and stress-rupture properties at high temperatures of four commercial heats of hot-work die steel of the 5-percent chromium type. While the life of some of the stress-rupture specimens tested at 600° and 800° F under loads of 90 to 95 percent of the tensile strengths was exceedingly long (tests stopped after 1,000 hr), other specimens failed almost immediately upon loading. Moreover, increased tensile and yield strengths at room temperature were observed in the specimens that did not fail at the higher temperatures. Further tests are being made to determine the cause of this behavior.

Crystalline Diffusion. Diffusion in crystals often occurs by the movement of vacant lattice sites through the crystal. In these cases, the diffusing atoms do not move by a series of random jumps. The correlation effect between the directions of successive jumps was theoretically investigated in studies of impurity diffusion and diffusion in a chemical concentration gradient. Expressions were derived which permit the calculation of atom jump frequencies from the experimentally determined diffusion coefficients.

Fatigue Properties of High-Strength Steels. Recent Bureau experiments indicate that retained austenite in the matrix of high-strength steels lowers the fatigue strength. The results also showed that fatigue stressing transforms retained austenite to untempered martensite, which probably causes the deleterious effect. These findings, made in tests on four different low-alloy steels with carbon content ranging from 0.44 to 1.06 percent, are expected to have practical applications in the processing of high-strength steels used throughout industry, and in the choice of steels for critical parts such as missile casings and aircraft structures.

Surface Reactions. In a study for the National Aeronautic and Space Administration on the influence of surface reactions in metal fatigue, it was found that polar organic compounds are much more effective than nonpolar organic compounds in improving the fatigue resistance of metal specimens. It has been known for some time that an oil film applied to a specimen surface gives some protection, and the present study indicates that the efficacy of the polar compounds in particular is due to their ability to prevent moisture from coming in contact with the metal surface.

Dislocations in Aluminum Alloys and Brass. In investigating the arrangement of dislocations (line imperfections) in aluminum alloys, single crystals of aluminum-copper alloys were subjected to several aging treatments to bring about precipitation of the $CuAl_2$ phase. The experiments showed that the precipitate particles are nucleated preferentially along dislocations, and then grow in a manner dictated by the crystal structure of both the matrix and the particles. As a result of the aging treatments used, the particles appeared as large needles. In some regions of the crystals the needles were oriented in the [112] directions. Observations were made with a projection X-ray microscope having a resolution of 1 to 2 microns.

Plastic deformation of a metal in one direction increases its resistance to further deformation in that direction, but greatly decreases its resistance to deformation in the opposite direction. This phenomenon, known as the Bauschinger effect, is being studied to develop information on the behavior of dislocations during deformation. An attempt is also being made with X-ray diffraction techniques to correlate the changes in the misorientation of the crystal lattice with changes in mechanical properties. It has been found thus far that in brass specimens a large part of the Bauschinger effect can be eliminated by heating at only 300° F.

Growth of Metal Crystals from Their Vapor. Experiments are in progress in the metal physics laboratory to evaluate the Burton, Cabrerra, Frank theory of crystal growth as applied to a simple, well-characterized

system. The theory, based on a growth mechanism through screw dislocations, has been qualitatively confirmed by the observation of growth spirals on a number of crystals, but quantitative confirmation is lacking because of the scarcity of experimental data. In the present work, a technique has been developed for measuring the weight of a metal crystal, growing in contact with its supersaturated vapor, as a function of time. Zinc crystals are being grown under various conditions of supersaturation. A method is being developed to convert the weight-versus-time curves obtained in these experiments to rates of growth.

Nuclear Magnetic Resonance. In pure indium metal, its nuclear magnetic resonance is not observed because of the metal's electric quadrupole moment and noncubic crystal structure. Recent experiments were therefore initiated with investigations of both the lead and indium resonances in alloys of these two metals. The indium atoms were dispersed in a cubic matrix of lead atoms which eliminated the quadrupole effects, and thus permitted a determination of the indium resonance in the metallic state. The shift of resonance (Knight shift) of the indium in these alloys was determined with relation to the shift exhibited by indium in indium-antimonide, a semiconductor.

Tuning in on the atomic nucleus. The nuclear magnetic resonance of metals and alloys is studied with the aid of a tuned radio transmitter and receiver. The metal sample is in the probe between the poles of an electromagnet (see page 73).

Corrosion Research

Stress Corrosion Cracking. Stress corrosion studies during the past year have been supported jointly by the Corrosion Research Council, the Atomic Energy Commission, and the Bureau. In one laboratory study, the progression of stress corrosion cracking in low carbon steel, magnesium, and stainless steel was successfully stopped by the application of cathodic currents. The significance of very high local stress concentrations in stress corrosion of low carbon steels was also established. A specimen was designed in which most of the variables can be controlled, and it was used to produce stress corrosion cracking in type 304 stainless steel exposed under stress at 450° F while in contact with an aqueous solution of 100 ppm sodium chloride. This specimen, serving as an autoclave, eliminates the difficulties ordinarily encountered in using autoclaves, and thus improves the precision of measurements.

Single Crystals. Studies of the influence of crystallographic orientation on the rate of film formation on copper single crystals immersed in oxygenated water were continued under the sponsorship of the Corrosion Research Council. A polarizing spectrometer was used to measure the rates. The experiments showed that an oxide film forms at the slowest rate on the octahedral face of copper, and somewhat more rapidly but at about an equal thickness on the cubic and dodecahedral faces. Pitting corrosion of high-purity iron single crystals was found to depend also on crystallographic orientation, with the dodecahedral face showing the greatest number of pits per unit area.

Free Radicals. The effect of free radicals on copper single crystals was studied at temperatures as low as 4° K. When reheated to room temperature, specimens that had been treated with oxygen passed through a microwave discharge (and therefore containing some atomic oxygen) were found to be covered with a stable film about 20 A thick. On specimens similarly treated with molecular oxygen, no film formation was observed. In similar studies, the refractive index of different gases condensed on gold was accurately determined for the first time. The gases included oxygen, ozone, water, carbon dioxide, nitrogen, argon, krypton, and ammonia. For details of the Bureau's free radicals program, see p. 36.

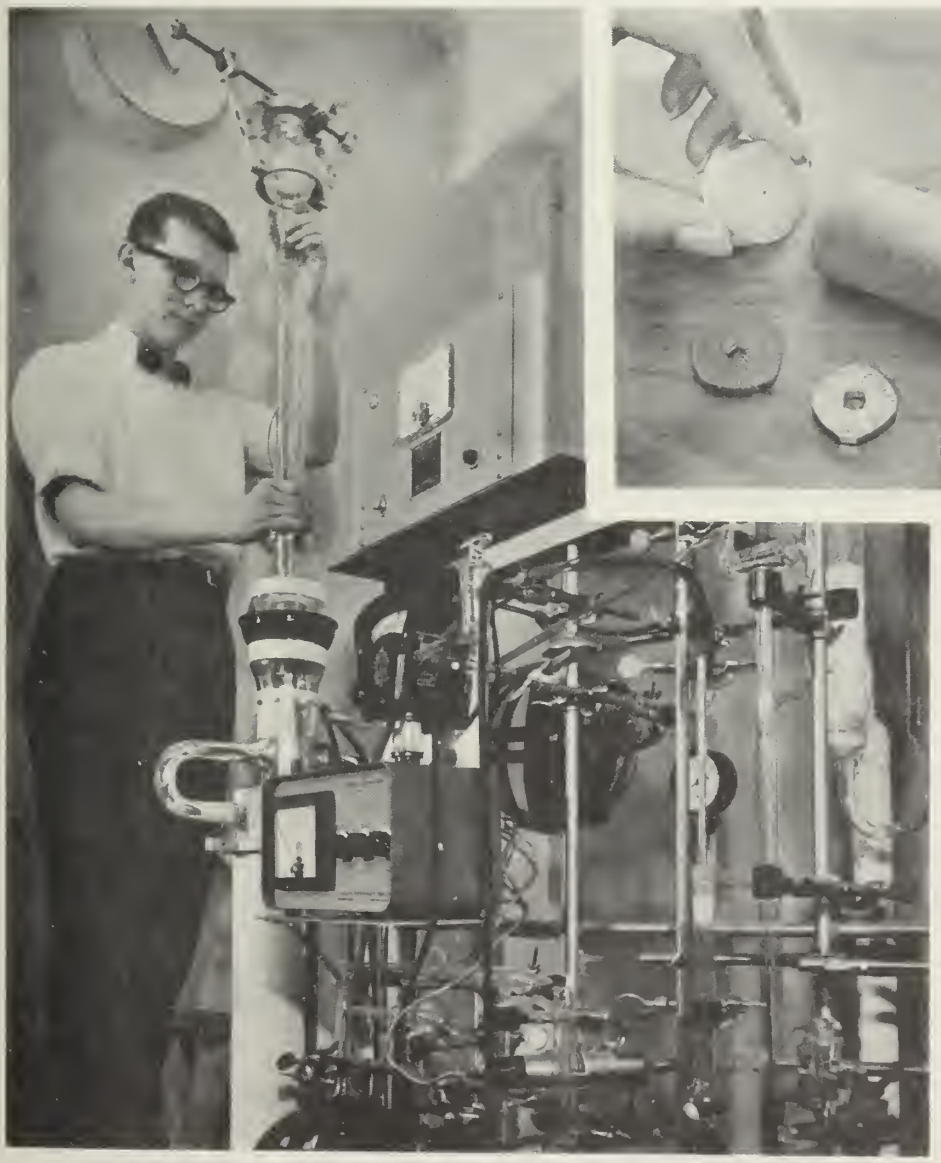
Preferentially Oriented Crystals. A method was developed for growing oriented single crystals of aluminum in many different shapes. A preselected orientation was obtained with a technique known as "seeding," and the desired cross-sectional shape was produced by growing the crystals in a vertical furnace. These specimens will be used to determine the relationship between lattice deformation and corrosion rates.

Uranium Alloys. In continuing studies of uranium alloys for the Atomic Energy Commission, it was found that small additions of any of the six platinum metals lower the melting point of uranium to certain minima, but the addition of more metal results in the formation of high melting point compounds. Binary phase diagrams of uranium and the platinum metals

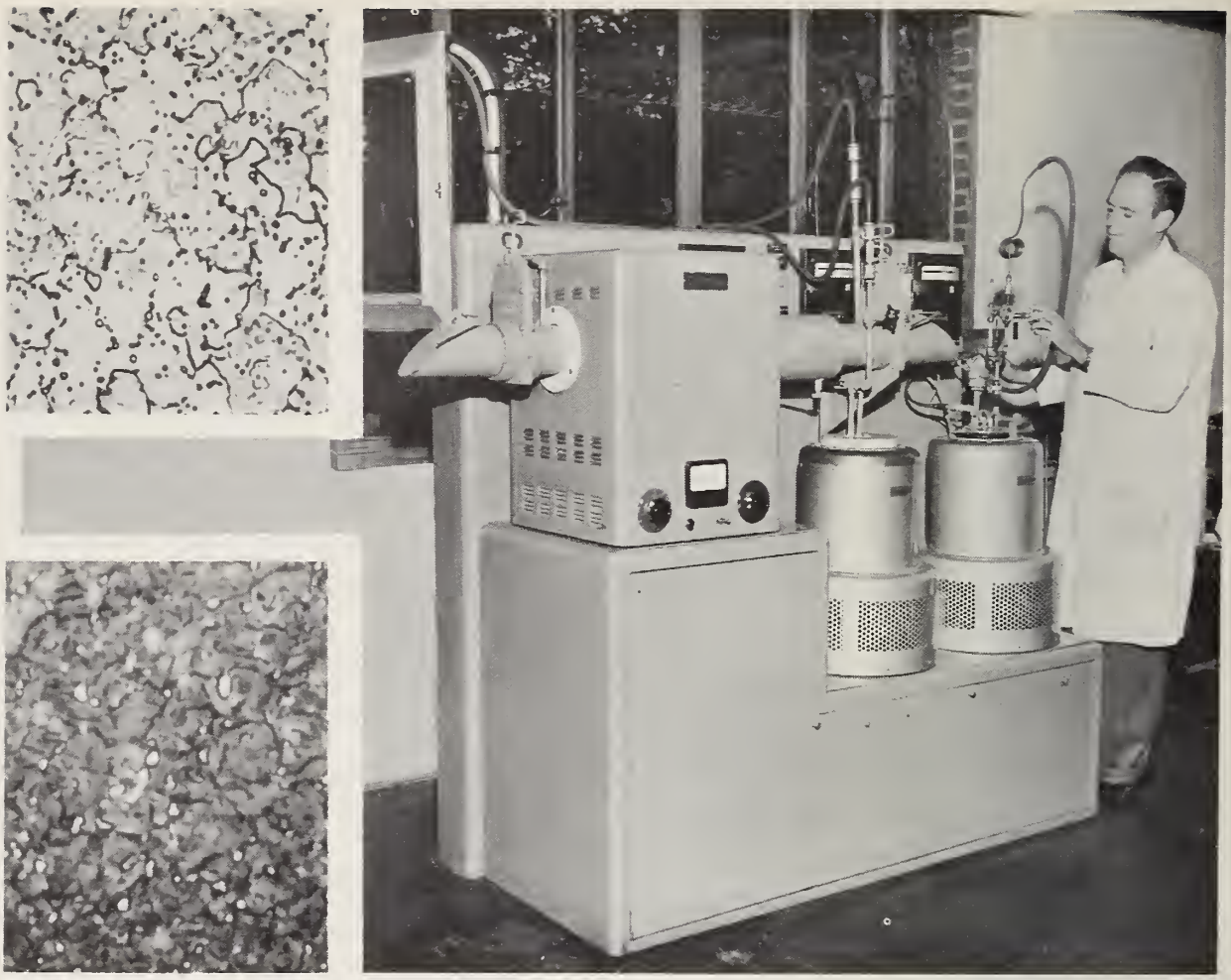
are being constructed. The existence of stable or metastable compounds, the presence of autectics and reaction horizontals, and the limits of solid solubility, as observed in the uranium-platinum diagram, are of practical significance in any uranium material.

The fissioning of uranium atoms in a power reactor results in the appearance of a number of metal atoms that may or may not be beneficial; however, to recover the uranium, these fission products must be removed. In pyrometallurgical experiments during the year two of the elements most difficult to separate from uranium (ruthenium and molybdenum) were removed by forming ruthenium-rich and molybdenum-rich compounds. The pyrometallurgical method also proved feasible in separating uranium as a uranium-cadmium intermetallic compound.

Improved Gage-Block Materials. Further experiments confirm a previous tentative finding that nitrided 410 stainless steel appears exceedingly promising as a material for ultra-precise gage blocks. The nitrided specimens were found to be corrosion-resistant to atmospheric and perspiration conditions. Moreover, their gaging surfaces are extremely hard and wear resistant, and can be finished to high degrees of smoothness, flatness, and parallelism. Measurements of nitrided 410 stainless steel blocks over a 1-year period indicate that they have the required dimensional stability as



The effects of atomic oxygen on copper single crystals were studied at temperatures as low as 4°K (left). A method for growing and studying preferentially oriented aluminum crystals (above) was developed to determine the role of crystal orientation in the corrosion process (page 74).



Annealed 410 stainless steel gage blocks nitrided in this equipment (right) are highly stable and corrosion-resistant. They represent a step forward in research directed toward the regular calibration of gage blocks to 1 part in 10 million. ***Insets:*** **Photomicrographs of unnitrided (above) and nitrided (below) 410 stainless steel (page 75).**

well as a substantially better stability than the best commercially available steel blocks (see p. 26). These results, however, cannot be considered conclusive because observations of commercial blocks over a 25-year period show that the results of measurements made for only a 1-year period are not necessarily indicative of future behavior.

Titanium Data Charted. Titanium and titanium alloys have relatively high strength-to-density ratios, and strongly resist attack by corrosive media. Hence they have considerable potential use in aircraft, airborne equipment, and chemical processing equipment. In designing for their successful application in these areas, however, engineers need information on the effects of low temperature, stress concentration, and stress system on the mechanical behavior of these metals. A study to obtain these data on annealed commercially pure titanium was, therefore, recently completed.

Tensile tests were made at 100°, 25°, −78°, and −196° C on circumferential notch specimens of different geometry. In general, the strength of the titanium increased with a decrease in temperature or an increase in triaxiality, independently of the stress concentration. Ductility decreased greatly with decrease in temperature or with an increase in either triaxiality or stress concentration. Thus, the increase in strength was usually accompanied by a decrease in ductility. The ductility of the specimens in which

the fracture crack was initiated at or near the root of the notch by stress concentration was usually less than that of specimens in which the fracture crack was initiated at or near the axis by triaxial stresses.

The results clearly demonstrate that the tensile behavior of unalloyed titanium at low temperatures cannot be accurately predicted from data obtained at a single temperature with specimens of a fixed notch geometry. The results also emphasize the importance of taking special care to eliminate notches. If they are unavoidable, attempts should be made to mitigate their embrittling effect by designing a notch with the largest permissible root radius.

Stainless Steel Properties Evaluated. An evaluation of the mechanical properties and microstructures of 17–7 PH (17 percent chromium–7 percent nickel) stainless steels was completed for Wright Air Development Center. Optimum mechanical properties at room temperature were obtained by a heat treatment slightly different from that recommended by the manufacturer. However, the best tensile and stress-rupture properties at 600° and 800° F were obtained by treating specimens as recommended. A definite embrittlement resulted from long-time exposures (100 or more hours) of heat-treated specimens at 800° F, with or without stress, but original properties were restored by reaging. No significant embrittlement was observed for similar specimens exposed at 600° F.

Unsuccessful attempts were made, by means of X-ray and metallographic examinations, to ascertain the mechanism of aging, and the identification of the precipitation-hardening compound. As precipitation-hardening stainless steels are now widely used both in missiles and in military arcraft, a study will be made of the structural and mechanical properties of foils of these steels as affected by heat treatment. Recently developed techniques for the direct observation of thin metal films with the electron microscope will be used.

2.9. Mineral Products

The Bureau conducts both fundamental and applied research on a wide variety of inorganic, nonmetallic materials. The primary objective of this work is the accumulation of basic data on the general properties, constants, structure, and behavior of these materials as an aid to both the producers and users of glass, refractories, porcelains, pottery, enamels, cermets, and cements. Because of the increasing need of fundamental knowledge to develop materials that can be used for structural purposes at high temperatures, more emphasis has been placed on high-temperature investigations.

New Data on Ferroelectric Materials. The ferroelectric oxides, of which barium titanate is the prime example, are important materials because they have wide applications as dielectrics in capacitors, as accelerometers, as memory devices for electronic computers, and as transducers in ultrasonic generators. Many ferroelectric properties of a substance, like those of ferromagnetic materials, are "structure-sensitive," that is, they depend strongly on such nonbasic properties of the specimen as grain size, impurity

content, distribution of internal strains, and lattice defects. To gain increased understanding of the behavior of these materials, it is necessary to study the properties and their effects. The Bureau is seeking to explain the electrical and magnetic properties of nonmetallic inorganic compounds, i.e., ceramics, in terms of structure.

To obtain reproducible measurements, several factors must be considered in studying these ceramics. The measurements are affected by environmental conditions (such as temperature and moisture), and by specimen preparations. To attain specimen uniformity, single crystals in pure form and with selected impurities are now being produced for experiments. To date, large aluminum oxide crystals have been grown and 50:50 $(BaSr)TiO_3$ (barium strontium titanate) crystals are being prepared.

By the addition of as little as 0.01 percent of the rare earths neodymium or samarium, the electrical conductivity of barium titanate at room temperature can be changed from values of the order of 10^{-10} to about 10^{-2} $(ohm\text{-}cm)^{-1}$. Above the Curie point, however, the conductivity decreases drastically by several orders of magnitude. Such an effect may be due either to a large change in the mobility or number of charge carriers. Single crystals are being used to study this effect and to check the validity of a proposed association of porosity, resistivity, and thermoelectric effect (Seebeck coefficient).

Phase Changes in Silicates. Cementing materials, including portland cement, are used in great quantities in the construction of highways, dams, missile takeoff pads, and nearly all types of buildings. These materials are complex products whose manufacture and use are still guided to a considerable extent by the long experience that has accumulated during the development of our flourishing concrete technology. The fundamental chemistry and physics of the processes are not completely understood, and therefore the guidance of fundamental knowledge toward possible new practical improvements is lacking. Some of the studies of high-temperature chemistry in silicates at the Bureau are designed to reveal such fundamental properties, structures, and mechanisms.

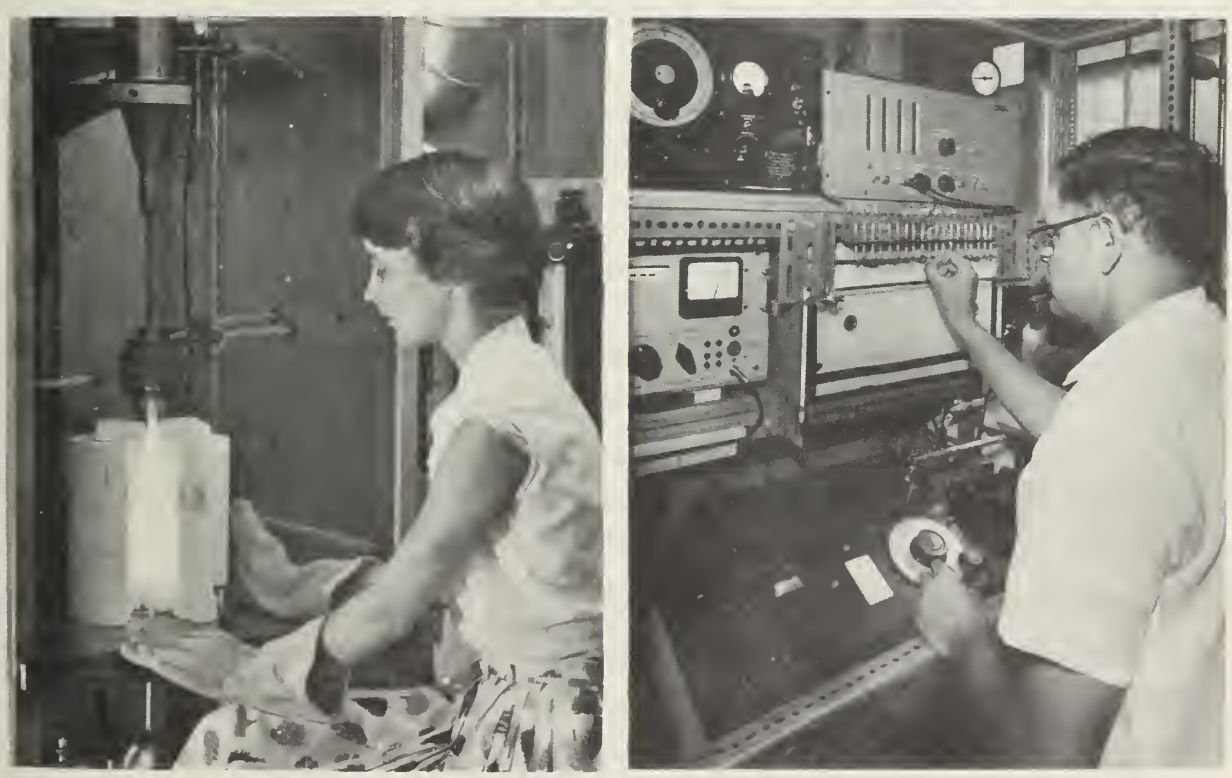
One study concerned dicalcium silicate, an active constituent of portland cement. The beta to gamma transformation of this substance, one active constituent of portland cement, exhibits a violent crystal inversion which causes crackling and dusting of the solid. The phenomenon is a significant industrial problem in the manufacture of portland cement. It is also exhibited by other compounds having analogous crystal structures, such as potassium sulfate.

As part of a research program partly supported by the Portland Cement Association, the polymorphism of dicalcium silicate was studied with high-temperature X-ray diffraction equipment developed by the Bureau. It was found that dusting occurs when the transformation of a sample is essentially complete. However, dusting does not occur when the substance includes certain impurities or is kept within certain temperatures, even though the transformations may be extensive. A critical temperature was found at about

1,420° C, considerably above the β-stability range, which controls the character of the transformation from β to the lower-temperature form. On cooling, samples without "protective" impurities showed dusting if they had been heated just above the critical temperature, but not if kept just below. The mechanism of this effect, and of the stabilization by impurities, is being studied by X-ray analysis of the crystal structures.

Strength of Glass at Elevated Temperatures. Inorganic transparent glasses are being considered for many applications at high temperatures. However, data on the mechanical properties of glass at high temperatures and the methods of obtaining such data, are insufficient. Thus the Wright Air Development Center is supporting a program for determining the mechanical properties of glasses over a wide temperature range. The data obtained aids the glass industry in improving presently available glasses as well as developing new high-temperature glasses, and enables the aircraft industry to better utilize the glasses that are available.

The modulus of rupture and the modulus of elasticity of a number of glasses were measured over a range of temperatures and after different heat treatments. Some compositions of annealed glass show an increasing strength and increasing modulus of elasticity with increasing temperature while other compositions decrease in both strength and modulus of elasticity with increase in temperature. Stress-rupture and creep tests have been made at room and elevated temperatures and the rate at which strength and tempering strain of tempered glass decreases at elevated temperatures has been measured.



Ferroelectric oxides have wide applications in capacitors, accelerometers, electronic computers, and ultrasonic generators. The equipment at right is used to measure the dielectric properties of such materials in constant-temperature environments. At left is a furnace used in growing single crystals of inorganic nonmetallic materials for study (page 77).

Infrared Transmitting Glasses. Glasses have many advantages over other materials for use in the infrared range. The optical properties of a homogeneous glass are constant in all directions, and crystal orientation is not a factor in the grinding and polishing process. A variety of refractive index values can be produced by appropriate composition changes, and most glasses are not affected by atmospheric moisture as are many crystalline materials.

Because little refractive index data on glasses are available for wavelengths beyond about 2.5 μ, the Navy Bureau of Ordnance asked the Bureau to undertake a special study. In cooperation with the Eastman Kodak Co., the refractive indices of 13 optical glasses and about 30 experimental glasses have been measured over the wavelength range from 0.43 to 4.25 μ. Transmittance curves for three thicknesses of the same glasses were also determined, from which absorption coefficients were calculated. Results of these experiments have been published.

An important problem in the use of glasses in infrared devices is the presence of an absorption band in the vicinity of 2.8 μ. This band is usually attributed to $(OH)^-$ radicals in the glass structure. The various methods which were used to reduce the absorption band are difficult for practical purposes outside the laboratory and may not be feasible in large-scale manufacture of glass. However, it was found that the addition of fluorides in the batch reduces the intensity of the water band. Relatively large amounts of fluorides can be used as a component of certain glass batches without causing opalescence or turbidity in the resulting glasses—if certain oxides, such as lanthanum oxide (La_2O_3) or tantalum oxide (Ta_2O_3) are also included. While this method was used only on a laboratory scale, it appears applicable to melts of any size.

Physical and Chemical Properties of Glass Surfaces. A long-range study of the surface groups of inorganic nonmetallic solids (i.e., the groups terminating the bulk structure) and of the effects of the proximity of the surface upon subsurface domains has been initiated.

One phase of this research is concerned with transport phenomena through vitreous silicates. Improved techniques have been designed to follow the movements of alkali ions through silicate glasses induced by electrical potentials and by concentration gradients. When glass is immersed in a diffusion sink, such as liquid water of a constant high purity, mobile alkali ions at the surface migrate from the vitreous material. This outward migration produces a deficiency of alkali ions at the surface and thus creates a concentration gradient within the glass. The gradient causes more alkali ions to flow through the vitreous material to the surface. An electrophoretic system removes the alkali immediately after entering the water, thus maintaining a constant *p*H. The electrophoretic current in the system is recorded and evaluated in terms of ionic flux from the glass surface.

The experimental values for the alkali flux from the glass surface and its activation energy are compared with theoretical curves derived from various

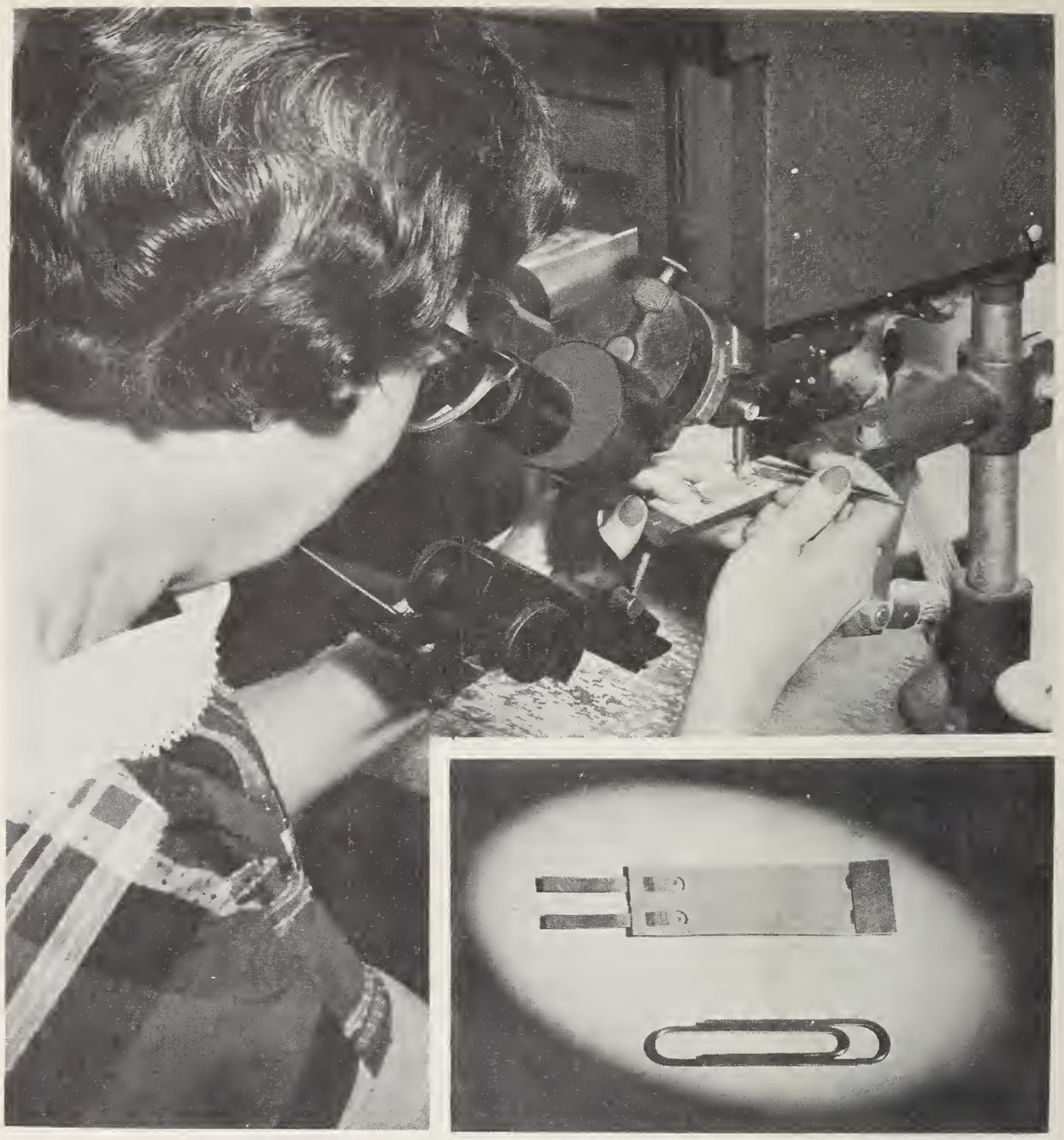
diffusion models. Conclusions are drawn concerning the transport mechanism. Further experimental work is aimed at obtaining concentration profiles through the surface domains which will serve as an additional criterion for the validity of proposed models.

Impact Coating for Rockets and Missiles. Nearly pure oxide coatings can be applied by projecting small molten particles against a metal surface. The resulting coatings, which are extremely hard and refractory, have numerous applications in missiles, rockets, and satellites. For example, a flame-sprayed alumina coating was applied to the outer skin of one of the Explorer satellites; other possible applications are in rocket nozzles and reentry nose cones.

The metal surfaces are covered with the refractory oxide by using such devices as flame-spray, plasma-jet, and shock-wave techniques. Existing knowledge regarding the application of these various types of particle-impact coatings is principally of an empirical nature; little is known of the scientific principles. To fill this gap, a basic investigation is being conducted for the Wright Air Development Center. Among the techniques of study that have been employed during the first year are high-speed photography, and microscopic examination of particles that adhere to glass slides upon impact.

Results obtained so far have helped to clarify certain mechanisms of the process. For example, it was found that molten particles from a rod-type, oxyacetylene gun are ejected from the gun in a series of spurts. Measurements with a streak camera, and with a rotating-disk velocimeter, indicated that the particles in each burst undergo acceleration during the first 3 inches of travel, beyond which their velocity progressively decreases. Practically all of the particles that adhere were found to be molten at the moment of impact. Flow of the coating material at this juncture is dependent upon the condition of the surface as well as its thermal properties.

Thermal-Radiation Standards for Space Vehicles. The successful launching of earth satellites, accompanied by increased emphasis on ballistic missiles and rockets, as well as design studies of vehicles for space travel, have resulted in an urgent demand for data on the heat radiation or thermal emission and absorption characteristics of a wide variety of materials. The metallic outer skin of a satellite or other space vehicle may be completely or partially coated with an appropriate ceramic material to control the temperature limits within which the overall balance between absorbed and emitted radiant energy is achieved. Such coatings, used in conjunction with an inner jacket of insulation designed for the purpose, establishes internal temperature limits that are suitable for normal functioning of the instrument and occupants, if any. Because needed data on absorptance, reflectance, and thermal emittance are not available, a number of different laboratories have set up equipment for determining these properties. However, results obtained on the same materials in the different laboratories have often been divergent.



Studies were made to develop strain gages and bonding cements which would perform reliably at high temperatures. These are necessary to determine the suitability of various construction materials for high-temperature applications. Here wires are being spotwelded in place in one of the final steps of fabrication. Inset shows a finished gage (page 81).

The Bureau has therefore undertaken a program for the Wright Air Development Center to develop standard techniques and instrumentation for the evaluation of spectral emittance, spectral reflectance, and solar absorptance. The study also includes establishment of procedures for the computation from spectra emittance data, of total emittance, solar absorptance, and absorptance for thermal radiation from such sources as rocket exhaust gases and nuclear weapons; also the selection, fabrication, and calibration of suitable materials for use as working standards of spectral emittance.

Apparatus has been assembled that will directly record the ratio of the intensities of radiation from (1) a metal specimen—with or without a ceramic coating—that is heated by passing a current through it; and (2) a laboratory blackbody furnace held at the same temperature. The appli-

cable range for this equipment is approximately from 250° to 1,000° C. Other equipment has been designed for the evaluation of spectral reflectance in the range 0° to 250° C under conditions simulating normal illumination and hemispherical viewing.

Standard specimens have been prepared from polished platinum and oxidized Inconel, and have been partially calibrated for normal spectral emittance (in cooperation with the Radiometry Laboratory).

Phase Equilibria in Rare-Earth Oxide Systems. Phase equilibrium studies of any chemical system are concerned with the effect of variations in environmental conditions (temperature, pressure, and composition) on the stability and chemical composition of coexisting phases—gas, liquid, or solid—of the system. Data on phase equilibrium are of vital importance for knowledge of the stability of high-temperature materials, formation of glasses, cements, metallurgical slags, and various alloys. Through use of heterogeneous equilibrium phase diagrams, experimental data on such combinations can be systematically correlated and extended to predict behavior for compositions and experimental conditions not yet explored. Such data are particularly important for a complete understanding of the behavior of ceramic products during firing and are most valuable as a source of information for the development of new products.

The oxides of the trivalent rare-earth ions are extremely useful refractory substances, having melting points generally above 2,000° C. Phase equilibria studies on systems involving these oxides find application in such fields as geochemistry, mineralogy, and ceramic technology.

As the initial step in a broad program, a reinvestigation of the polymorphism of the rare-earth oxides was undertaken. Previous work was essentially confirmed showing that samarium oxide, europium oxide, and gadolinium oxide have stable B-type structures at elevated temperatures. Furthermore, it has been definitely established that all of the phase transformations occurring in the trivalent rare-earth oxides are nonreversible.

In addition, a survey was made of the subsolidus, solid-state reactions that occur under equilibrium conditions for different combinations of the trivalent rare-earth oxides. Selected compositions in over nineteen different systems were studied by X-ray diffraction techniques. A graph of the average ionic radius of the constituent cations versus all possible compositions of double oxides was drawn from the data to show specific regions of stability for the various structure types found in these systems. From this graph the subsolidus phase diagrams can be predicted for any multicomponent rare-earth oxide system.

Solid-Gas Reactions Involving Light-Metal Oxides. High-temperature thermodynamic data on the light elements—lithium, magnesium, aluminum, and beryllium—and their compounds are essential for the prediction of chemical reactions at high temperatures and for a systematic evaluation of prospective high-energy solid propellants for rockets (see 2.3, p. 32). To obtain this basic high-temperature information, the energies

and equilibrium proportions of the light-metal oxides are being determined in the solid, liquid, and gaseous states at pressures up to 100 atmospheres and temperatures up to 6,000° K. A survey of the literature on solid-gas and liquid-gas reactions involving oxides of the light elements has been undertaken for the Advanced Research Projects Agency to obtain the most precise values to compute tentative thermodynamic tables.

Using existing phase diagrams, new estimates of the heat of fusion of alumina were obtained. The values varied widely and indicated that no special merit should be attached to the currently accepted value of 26 kcal/mole. A new, but rough determination of the melting point of alumina gave a value of 2,030±5° C. The limited amount of data, obtained with the aid of a solar furnace, are consistent with the existence of a gaseous AlOH molecule at temperatures above 2,000° C.

Recent activity has been devoted to designing and testing equipment to undertake three principal tasks: A more refined study of the vaporization of Al_2O_3 in water vapor using an arc-image furnace, a redetermination of the vapor pressure, and study of the rate of sublimation of Al_2O_3 above 1,600° C.

High-Temperature Strain Gages. Reliable strain measurements are needed for analyzing stresses in structural materials for high-temperature applications (see 2.6, p. 60). Such characteristics as strength, durability, and dimensional stability are of critical importance in the components of aircraft powerplants, aircraft wing structures, guided missiles, and certain types of nuclear reactors. Conventional electrical resistance gages, which consist of fine-wire filaments bonded with organic resins, are adequate for use up to about 175° C; however, at higher temperatures the organic binder deteriorates. To increase the temperature limit for this type of measurement, a prefabricated gage which could be bonded to test structures with a ceramic cement was developed in a previous phase of this work, under the joint sponsorship of the Bureau of Aeronautics and the Wright Air Development Center. This gage, which has since been commercially produced, performed satisfactorily up to about 425° C, but above this temperature electrical leakage increasingly affected the measurements of strain.

During the past year a new cement composition was developed which has higher electrical resistivity in the range 425° to 1,000° C than any known commercial product. The greatest improvement was within a zone near 700° C, where the resistivity exceeded that of the best of the commercial cements by a factor of 100.

Because a low cement curing temperature is essential for many applications of strain gages in testing large structures, a study was made of the effect of cement curing temperature upon gage response. It was observed that the uncured cements became conductive at intermediate temperatures, with the result that the gages were short circuited. Application of a fused-on ceramic coating to the resistance element and leads, prior to assembly of the gages, prevented the short circuiting.

Dynamic Mechanical Properties of Refractory Oxides. Because of the general trend toward higher temperatures in technology, the mechanical properties of refractory oxides at elevated temperatures have recently received increasing attention. To extend the basic understanding of the mechanical properties of various materials, and to relate these properties to structural defects, dynamic resonance methods have been used for determining elastic and inelastic behavior of these materials over a wide temperature range (−190° to 1,700° C).

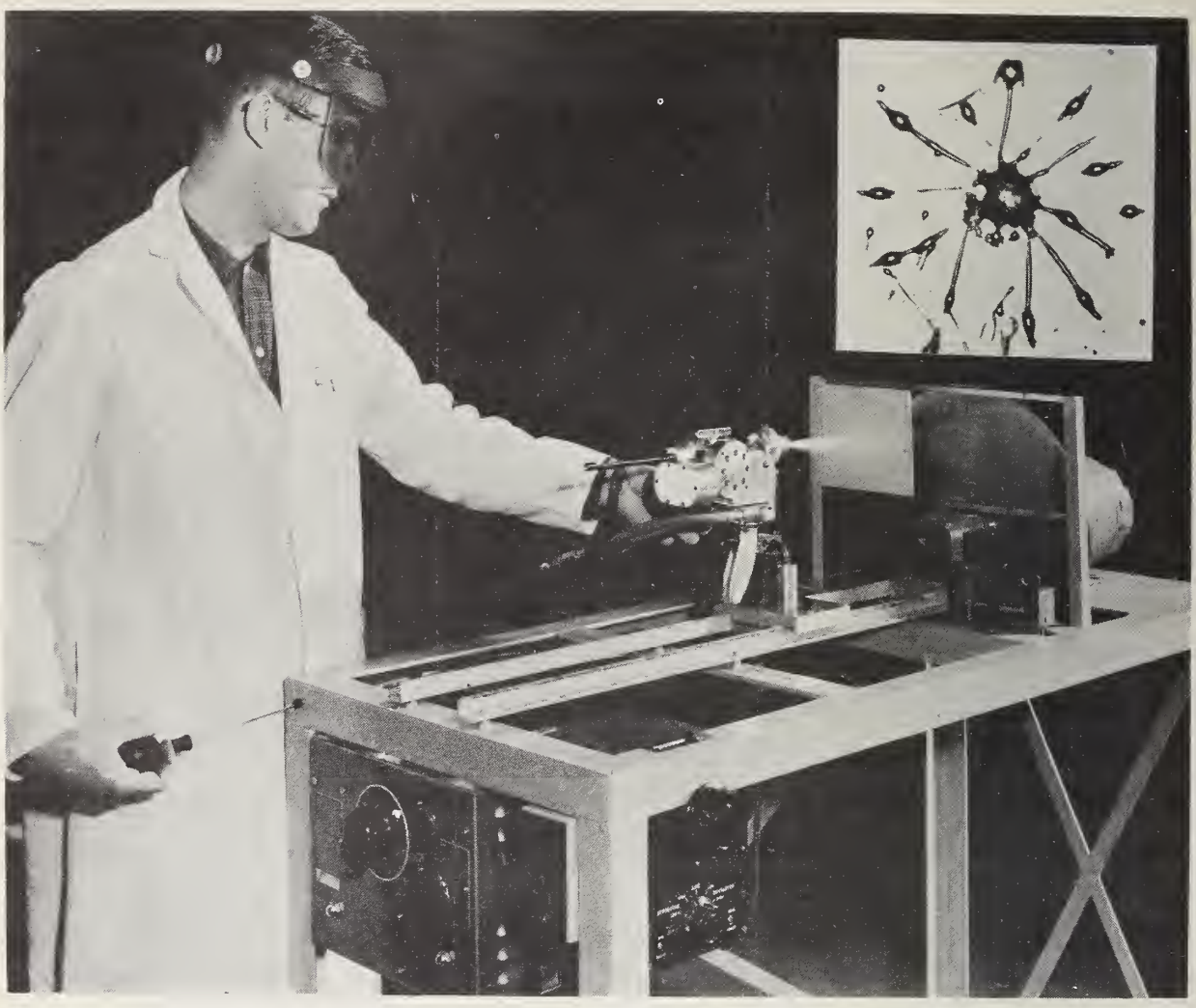
As part of a program to determine strength of ceramics at elevated temperature, the strength of aluminum oxide single crystals (sapphire and ruby) were studied between 600° and 1,000° C. Because of their heat- and corrosion-resistant properties, materials such as aluminum oxide find application in aerodynamics where high-temperature load-bearing structures are required. Such ceramics are also of special interest in electronics and electrical insulators.

The strength of polycrystalline aluminum oxide is known to decrease with increasing temperature above 800° C. However, in one set of measurements on single-crystal aluminum oxide, crystal strength increased with temperature in this range. The study at the Bureau supports the theory that this increased strength may be caused by very small amounts of plastic deformation. That is, failure may have begun at points where the local stress was much greater than the average applied stress. Plastic deformation might then have reduced the degree of stress concentration with the result that a larger average stress could be sustained before failure occurred.

In another study, the effects of impurities are being studied by comparing the results for high-purity materials with those of deliberately doped specimens.

Infrared Absorption Spectra of Compounds Under High Pressure. The basic characteristics of matter are determined by the nature of atomic and molecular interactions. Although the broader aspects of interactions between adjacent molecules are understood, a detailed evaluation has not been made of the disturbances produced by interactions between more widely separated molecules. Spectroscopic evidence has been found which shows changes in molecular structures occur under pressures of 30,000 atmospheres. Reactions produced under such pressure may result in producing denser phases or polymorphic forms having uniquely different properties from those of the parent material. Infrared spectroscopy is used in this work because the frequencies of absorption bands are determined by the characteristics of the molecular units present, such as the masses of the oscillating units, the forces between them, and the force fields of adjacent molecules.

A pressure cell has been constructed using a pair of type II diamonds for study of infrared spectra of solids in the 1- to 25-micron region. Spectra can be studied routinely to calculated pressures as high as 60,000 atm and occasionally to pressures of 100,000 atm or more. A large number of such organic compounds as substituted benzenes, and such inorganic compounds



Refractory coatings have numerous applications in missiles, rockets, satellites, and in other high-temperature environments. Here an oxyacetylene gun is used to flame-spray an aluminum oxide coating. Inset shows the flow behavior of a molten aluminum oxide particle impacting a hard surface (page 84).

as carbonates, nitrates, silicates, and sulfides, have been studied with special emphasis on changes in bond characteristics caused by pressure. Infrared patterns have been obtained on water, normal ice, and high-pressure forms of ice. The data on the high-pressure forms of ice are the first that have ever been obtained showing the change in bond characteristics between hydrogen and oxygen.

Structure of Solids Containing Free Radicals. So great is the tendency of most of the simple free radicals to combine with each other that they cannot be obtained in a pure crystalline form and so must be studied by other methods. Thus thin films of the polycrystalline solids formed by freezing gases on a cold surface are being studied by low-temperature X-ray diffraction techniques. From these experiments conducted in connection with the Free Radical Program, the degree of crystallinity, bond angles and distances, and structural changes that occur during warmup are being determined. The information obtained is used in interpreting the results of other types of experiments on solids containing trapped free radicals (see also 2.3, p. 36).

Gases studied by this technique include nitrogen, argon, krypton, carbon dioxide, xenon, diborane, oxygen, ozone, water, hydrogen peroxide, and

ammonia. These have been classified according to the degree of crystallinity of the solid formed by deposition at 4.2° K. X-ray diffraction patterns of the various crystalline phases have been recorded, and orientation texture, annealing characteristics and polymorphism have been studied in some detail.

Standard X-ray Diffraction Patterns. Standard X-ray diffraction patterns in the form of card files, are widely used in research and industry as a rapid and accurate means of identifying crystalline materials. As part of a continuing program for the preparation of these patterns, the Bureau has been studying and recording data in close cooperation with the Joint Committee on Chemical Analysis by Powder Diffraction Methods (ASTM and American Crystallographic Association). During the past year 70 standard patterns have been published, and approximately 250 additional X-ray patterns have been indexed for inclusion in the Powder Data File. The ninth volume of NBS Circular 539 (Standard X-Ray Diffraction Powder Patterns) is in press.

2.10. Building Technology

The Bureau serves as a central agency of the Government for the advancement of scientific knowledge of building materials, structural elements, environmental engineering processes, and safeguards in building construction and maintenance. It also assists other government agencies in solving special technical building problems. Research emphasis is directed toward increasing knowledge about the factors affecting the performance of buildings, their facilities and equipment, the behavior of structures under various conditions, and the nature of the physical processes that result in changes in materials in different environments. Much of the data are used in the development of specifications and standards prepared by technical organizations, and in manuals of design.

During the past year a new method was developed for measuring the thermal conductivity of solid materials. Significant progress was made in the development of technical data on the physical properties of insulating concretes and joint sealing materials. Further progress was made on methods of determining the surface flammability of materials and new techniques were applied in studies of the degradation of asphalts.

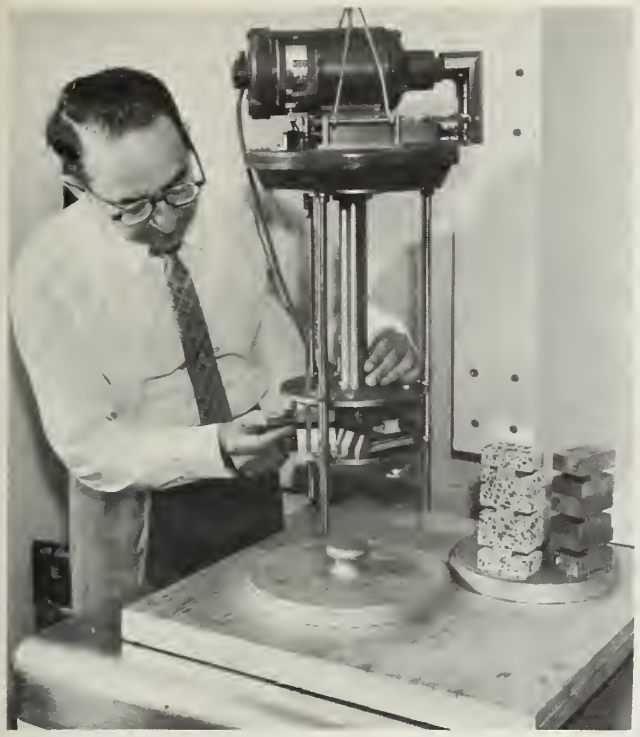
High-Temperature Thermal Conductivity. As part of a broad research program concerned with the properties of materials at high temperatures, the Bureau has been studying methods for measuring the thermal conductivity of insulations, solids, and metals at high temperatures. A new method for determining thermal conductivity by a steady-state comparative method was developed, applicable to homogeneous materials of low to moderate conductivity in the form of flat slabs, or hollow cylinders. A comprehensive mathematical analysis of the method as applied to flat slabs was made. A small apparatus based on the new method was built to measure the thermal conductivity of explosives and solid propellants for rockets.

A larger apparatus for experimental purposes is being built of materials that can be used over the temperature range from below −195° C to above 1,200° C. This equipment will replace the three separate sets of apparatus currently in use that cover only the range from −170° C to 750° C. Potential advantages of the new method include the possibility of supplying practically identical replicate specimens to other laboratories to promote uniformity of thermal conductivity measurements, and the possibility of conducting intercomparisons of thermal conductivity results obtained by several distinctly different absolute methods.

Thermal Conductivity Reference Specimens. For several years, various laboratories have submitted to the Bureau specimens of insulating materials for an accurate determination of thermal conductivities. Laboratories use these specimens as references for calibrating thermal conductivity measuring apparatus. Requests for this service have been increasing. In order to satisfy such needs more quickly, and to avoid problems arising from use of unsuitable materials, two materials having satisfactory characteristics of homogeneity and stability (glass-fiber board and gum rubber) were selected and stocked. Reference specimens can be prepared from this stock and the thermal conductivity measured at the specified temperatures. Such services are available under the cost fee schedule to governmental, industrial, and university laboratories.

Physical Properties of Insulating Concretes. In recent years lightweight aggregate and cellular concretes have been used as thermal insulation for roofs, walls, and underground steam lines. In order to develop satisfactory specifications for these materials, the Bureau has been studying the properties of various insulating concretes for the Department of Defense. The study includes cellular concrete containing no mineral aggregates and concretes containing a lightweight aggregate, perlite, or vermiculite. Compressive and indentation strengths were determined as functions of composition and proportions, density, curing and age, moisture condition, and size and shape of test specimens. The rate of drying and shrinkage were also determined as functions of original moisture content, cement content and aggregate type.

Joint Sealing Materials. The premature failure of joint sealants in buildings, resulting in leakage of rain water through walls, is regarded as one of the most costly and troublesome problems in building maintenance today. The Department of Defense asked the Bureau to study the properties of the newest types of rubber-based mastics for sealing joints in structures where movement is expected and air and watertightness is required. Some of the properties being studied are adhesion, cohesion, durability at high and low temperatures, staining tendencies, color retention, viscosity, flow, and hardness. Behavior of the sealants in test joints that are extended in width every 3 months are being studied under natural weather conditions. A number of sealant manufacturers are cooperating in the program by supplying the samples for the investigation and by exchanging technical data pertaining to methods of testing.



Left: **After being subjected to heating, soaking, and freezing exposures in the laboratory, rubber-based calkings for masonry construction are tested for adhesion and cohesion in this machine. Accessory blocks used in the test are concrete, brick, wood, and other building materials.** ***Right:*** **NBS test equipment which forms the basis of the recently issued Interim Federal Standard for measuring surface flammability of building materials (pages 88, 89).**

Mechanism of Fire Extinguishment. The effectiveness of dry chemical powders for control of fires is under investigation for the Bureau of Ships. In one phase of this study, the minimum rate of powder application required to extinguish flammable liquid fires ranging in size from about 1 in. to 22 in. in diameter was determined. It has also been found that considerable confidence can be placed on the use of very small experimental fires to measure the extinguishing efficacy of dry powder agents.

Surface Flammability of Materials. The ease with which the interior finish of a building ignites and burns is an important factor with respect to the fire safety of occupants of the building. Building and code officials specify limits on the finish flammability depending on type of building occupancy expected.

Since announcement of the development of the radiant panel flame spread test method at the Bureau, a large number of industrial research laboratories have installed test equipment of this type. To insure uniformity of test results being obtained with use of the test equipment, an interlaboratory study showed that excellent reproducibility could be achieved, with apparatus developed at the Bureau, provided slight modifications were made in the recommended calibration technique. These changes have been incorporated in the recently completed Interim Federal Standard No. 136 which was prepared at the request of several governmental agencies.

Standards for Refrigerated Trailers. A study of methods for circulating the chilled air inside refrigerated trailers is now underway for the U.S. Department of Agriculture to supplement the equipment rating program adopted last year. Current experience indicates that all parts of the frozen

food cargo are not now being adequately protected in many cases because of lack of technical information on the air distribution required inside the vehicle.

Underground Pipe Insulation. The Bureau is carrying on a continuing program for developing technical data on underground pipe insulating methods for the Army Corps of Engineers, the Navy Bureau of Yards and Docks, and the U.S. Air Force. The results of these studies so far have been used to modify the criteria for underground pipe insulating systems now used throughout the Federal Government and as a guide in preparing a performance specification for all materials designed for such applications.

Asphalt Studies. In cooperation with the Department of Defense, extensive laboratory and field studies were made to determine the practicability in service of self-sealing asphalt shingles made available recently by several manufacturers. The time of sealing at various temperatures, the temperatures of the shingles exposed on roofs, and the resistance of the shingles to winds up to 60 miles per hour were determined. Field studies were made in both northern and southern locations to provide a variety of climatic conditions. From the data obtained in the laboratory and field studies, suggested criteria for the performance of self-seal shingles have been furnished to the sponsors.

Investigations of the mechanism of degradation of asphalt and its products was continued. The effects of chemical additives on asphalt durability, infrared spectral properties, and the absorption properties of asphaltenes were studied. The stable free radicals in asphalt were investigated with electron spin and resonance techniques, and the oxidative changes occurring during accelerated weathering tests were analyzed by chemical methods.

Wear Resistance of Flooring Materials. The compositions and constructions of floor covering materials have undergone considerable change in the past several years, thereby creating a need for reliable methods for evaluating the resistance to wear of the newer materials on which there is little field experience. The Bureau has been cooperating with several European laboratories in tests of a series of such representative materials as vinyl plastics, rubber, and asphalt. Specimens have been exposed to actual wear tests in a Paris subway, in elevators in Berlin and Stuttgart, and in buildings at the Bureau in Washington. Results to date show little correlation between actual wear in service and laboratory tests with abrasion machines.

Lightning Hazards of Buildings. The use of metallic siding and roofing for buildings and metallic reflective insulation in buildings has raised a question as to whether these materials, if not properly installed, increase the probability of fires resulting from lightning discharges. Using these metallic materials with sections of typical frame buildings, the Bureau has demonstrated by laboratory tests that flammable materials could be ignited by high voltage discharges when the metallic materials were not grounded. Similar results were obtained with ungrounded prefabricated metal chimneys.

The effectiveness of dry powders in extinguishing fires of flammable liquids was studied (page 89).

Safety Codes. A revision of the American Standard Safety Code for Head, Eye, and Respiration Protection, sponsored jointly by the Navy Department, the Bureau of Mines, and NBS, was completed. The revision discusses the use of transparent plastics in goggles and face shields and includes many new performance requirements.

The Code for Protection Against Lightning, sponsored jointly by the National Fire Protection Association, the American Institute of Electrical Engineers, and the Bureau, was revised. The revision includes additional details on the protection of tanks containing flammable liquids.

2.11. Applied Mathematics

The Bureau maintains a central applied mathematics facility which conducts basic and applied research and renders advisory services to other government agencies in various mathematical fields. Equipped with modern computing aids, including high-speed digital computers, the facility plays a significant supporting role in the Bureau's research and development program. The work covers a wide range of investigations and applications in engineering and the physical sciences. In addition, an increasing share of the Bureau's mathematical effort is devoted to applying digital computers to problems of the type encountered in business management and operation, sometimes referred to as "data processing" problems. The facility also provides consultation on the statistical design and interpretation of experiments.

A vigorous research program is directed toward creating and improving mathematical methods for science, engineering, and management. It is concentrated in three main areas: The program in numerical analysis is aimed at developing methods of computation with special emphasis on the use of modern high-speed equipment; studies in classical applied mathematics are devoted to the analytical, rather than the numerical treatment of physical problems; and research on mathematical statistics is concerned with the design and interpretation of experiments, and with reliability and life testing of equipment.

Numerical Analysis. Research in mathematical topics applicable to numerical analysis was conducted with the support of the Office of Naval Research. Such research is of vital importance in its contribution to the effective application of modern digital computing equipment. Topics covered included incidence matrices, modular functions, groups and subgroups, and the convergence of iterative procedures for the computation of characteristic roots and vectors.

Training Program. The second program in Numerical Analysis, sponsored jointly by the National Bureau of Standards and the National Science Foundation, was held at the Bureau during the spring of 1959. Intensive training in numerical analysis was given to nine university teachers who are experts in related mathematical fields. This concentrated study will provide the background which will allow them to teach and conduct research in numerical analysis and to direct university computer centers. The national shortage of mathematicians competent in programing for high-speed automatic digital computers and in carrying out the required numerical analysis motivated the presentation of this course.

The program was divided into three parts: (1) Lectures on coding and programing for electronic digital computers; (2) lectures on theoretical and practical topics in numerical analysis; and, (3) and a problem assignment in which each participant prepared a major code, ran the code on the machine, and interpreted the results.

New Eigenvalue Method. The eigenvalues and eigenvectors of a matrix are necessary to the solution of such a wide variety of problems that computation laboratories must have available a selection of methods and codes for computing these functions. A new method for computing dominant eigenvalues was coded and tested by the Bureau. This method can be applied to matrices with nonnegative elements or to those which can be put into this form by certain simple transformations. In addition it is iterative and can be carried out with extremely simple arithmetic operations. Applied to a matrix poorly conditioned for many matrix operations, the method yielded the answer to 5 places after 63 iterations.

Stability of Recurrence Relations. Recurrence relations are commonly employed in computing because they are convenient to formulate and easy to code for electronic computers. Numerical analysts therefore look for these relationships and utilize them whenever they can. However, despite their many attractive features, recurrence relationships possess a

property which may cause difficulty. Unless care is taken, they may allow so much roundoff error to accumulate that the results of the computation may be invalidated. This phenomenon is known as "instability."

A study has been made of the roundoff accumulated when systems of first order recurrence relations are used. It has been known for some time that the stability of a system is not independent of the direction in which the recurrence is carried out. Sometimes a computation which shows instability for increasing parameter values will be perfectly stable for decreasing values. By making use of such facts, the Bureau developed criteria for the direction of computation. The criteria were applied to the calculation of the incomplete gamma functions, which occur in various molecular computations.

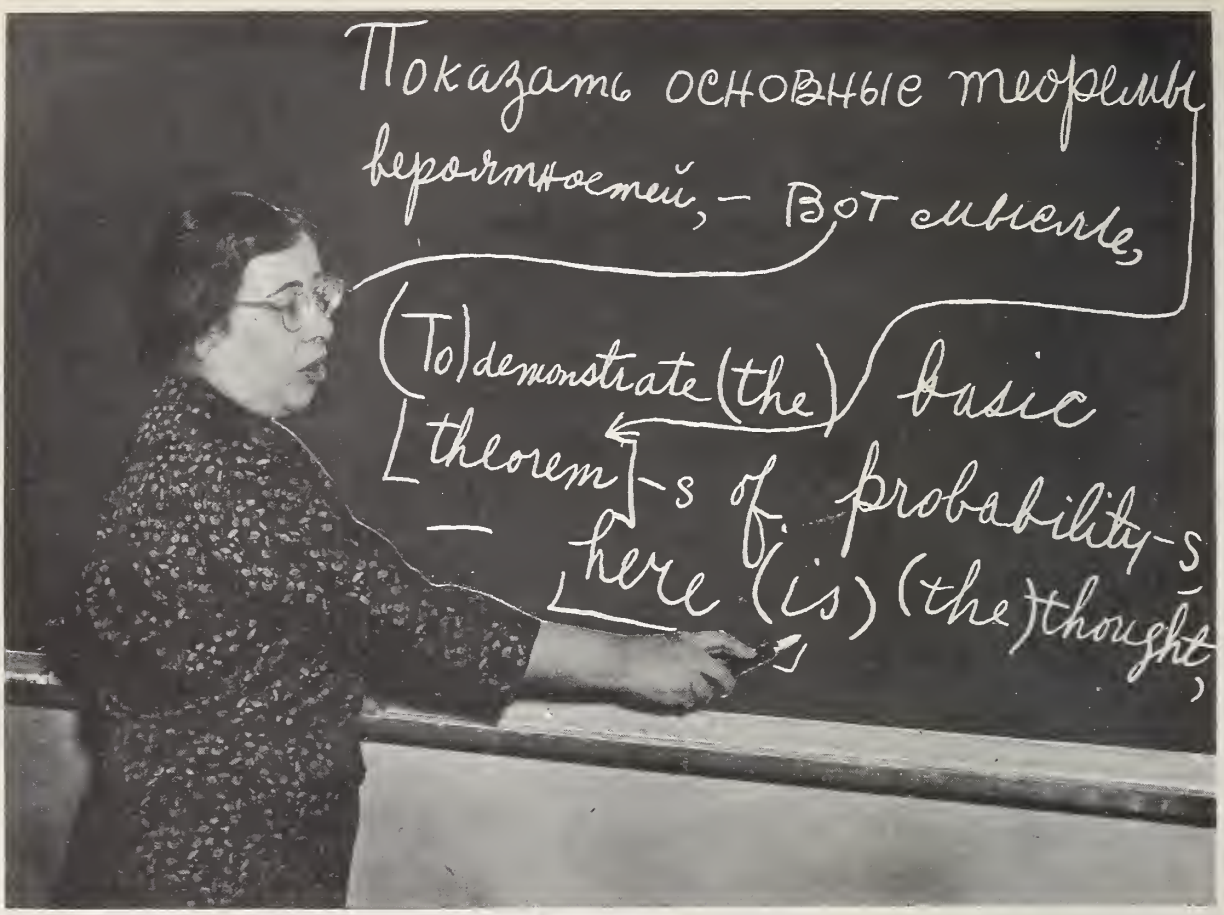
Machine Translation. Machine translation provides a new approach to producing English text from Russian technical literature. A translation scheme presently being studied by the Bureau for the Army Office of Ordnance Research instructs an electronic computer to rearrange and weld together English correspondents of Russian words to make a meaningful reproduction of the intent of the original. Initial simulation on a high-speed electronic computer indicates the practical applicability of this scheme.

The program first instructs the machine to transform the words of a Russian sentence into a highly condensed representation for matching in a glossary. The machine is then told to recognize the syntactical relation between the words. After this, it puts together the corresponding English words into a meaningful sentence. With the improvements and shortcuts that will be developed in the programing and by using the advanced computers under construction, it is estimated that the cost will be about the same as for a human translator.

Mathematical Tables. Considerable progress has been made with the *Handbook of Mathematical Functions,* which the Bureau, with the support of the National Science Foundation, is compiling. Of 29 projected chapters, 20 have been finished and circulated to an advisory committee and 5 others are being edited prior to circulation. Accompanying tabular material has been prepared on an automatic card-operated typewriter for photo-offset reproduction.

A volume of Tables of Osculatory Interpolation Coefficients and one of Integrals of Airy Functions were published. Three volumes of tables are now in press. These are: Sievert's Integral, Coulomb Wave Functions of Order Zero, and the Bivariate Normal Distribution Function.

Improvement in Facilities. During the past year the capacity of the electronic computing installation was greatly increased by expanding the high-speed memory to 32,000 words and adding an auxiliary magnetic-drum memory. The machine was placed on three-shift operation. In addition to performing computations arising in the work of the Bureau, it serves as a standby facility for the Weather Bureau, carries the main computing load of the National Aeronautics and Space Administration's Theoretical Division, and serves numerous other Federal agencies.



Experiments in machine translation indicated a promising approach to practical production of English text from Russian technical literature (page 93).

Digital Computation. Several standardized computer programs of a general nature are available for use within the Bureau and in other Federal agencies. These programs can be applied to curve fitting by the method of least squares, to solving systems of linear equations, to determining eigenvalues and eigenvectors, and to regression and Fourier analysis. Many older programs were revised in order to take advantage of the greater machine memory. For instance, in the problem of interpreting X-ray diffraction patterns for crystal structure analysis, the computing time has been cut in half. A general-purpose orthonormalizing code was revised not only to gain time but also to give a more detailed output. Computers were also applied to various problems arising in scientific fields. Some of the calculations made were the determination of gas tube characteristics, intensity functions and cross sections for scattering of light from spherical particles, absorption spectra of ferrides, and microwave absorption by large molecules.

In the data-processing field, important problems included bid evaluation, allocation of radiofrequencies, simulation of postal operations in connection with the Bureau's study of post office mechanization, and simulation of military engagements. In a new venture, the electronic computer was used to produce wiring diagrams automatically for the design of the Bureau's new Pilot computer.

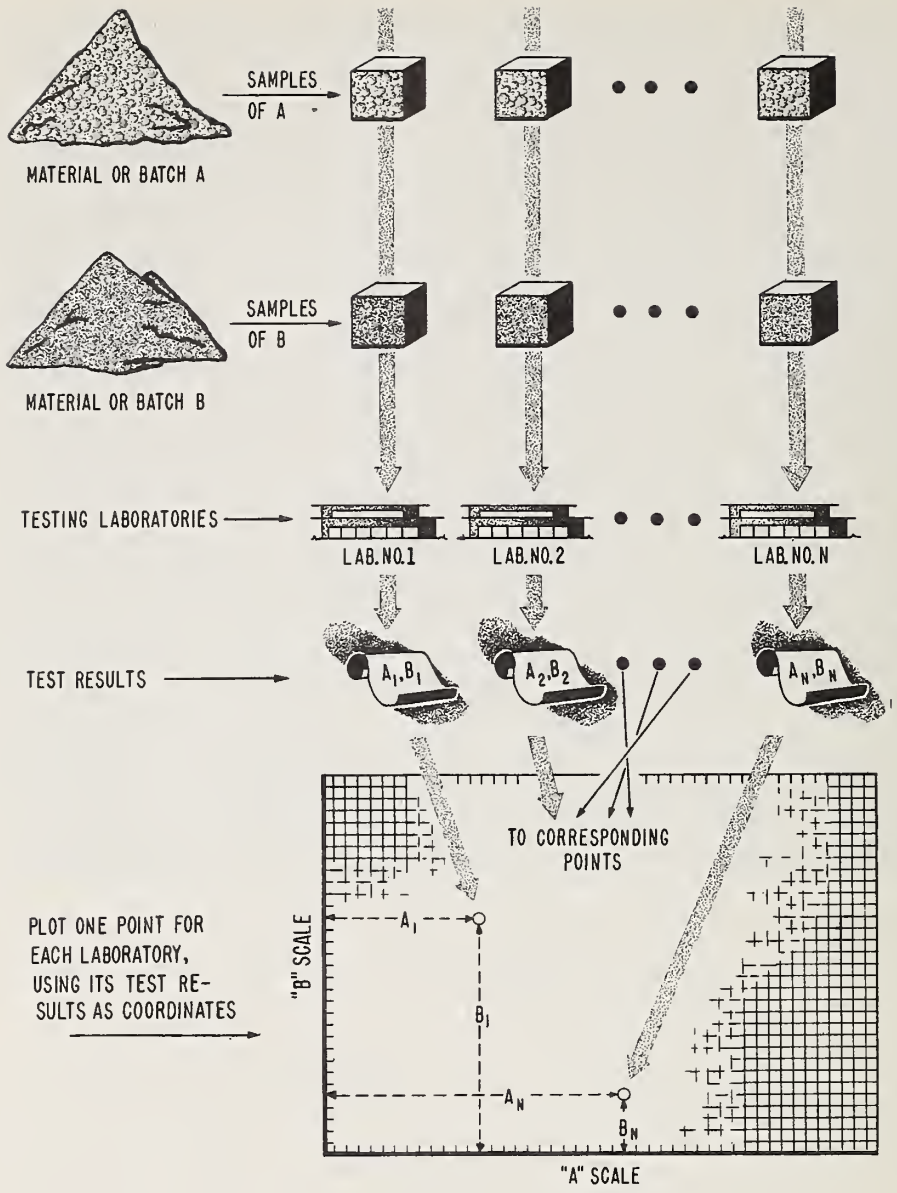
In preparation for the addition of an off-line printer to the computation facilities, programs were developed for the automatic plotting of curves and for the automatic large-scale dumping of data onto magnetic tape.

Design of Experiments. New mathematical methods were developed for selecting subsets of treatment combinations in multifactor experiments. This has made it possible to extend designs for experiments, formerly limited to those involving factors at just two or just three levels, to those involving a mixture of two and three levels. Until now no theory for the construction of fractional factorials of the mixed series has existed, i.e., for designs involving m factors each at two levels and n factors each at three levels. Formerly, experiments involving the simultaneous variation of a number of background factors had to be interpreted by running tests at all possible combinations of a fixed number of levels for each of the several factors under study. This method required a number of measurements often prohibitively large. In addition, it was often not practical to plan an entire experimental program in advance. Fractional factorial designs are a means for overcoming these disadvantages and their use has become common in recent years because of the availability of plans for the 2^m and 3^n series. This latest work under the sponsorship of the Bureau of Ships has led to a catalog of designs to the mixed series as a sequel to the catalogs previously prepared for the 2^m series and the 3^n series.

Life Testing and Reliability. Research on methods for the analysis of data from life-testing experiments has led to the development of exact methods to replace the currently used approximate methods. In life-test experiments a number of nominally identical items (tubes, lamps, and electronic components, for example) are run under a given set of operating conditions and the time to failure recorded for each item. The analysis of data from such tests when a spectrum of operating conditions is employed has previously been handled by methods worked out for other situations. These give only approximate results for the distributions encountered in life-testing phenomena. The new procedures provide criteria for extrapolating the results of accelerated environment tests to provide estimates of performance under normal operating conditions.

The study of life-testing procedures is part of the program of research on measurement and prediction of the "reliability" of complex systems. Another aspect of this program has been the study of mathematical models for representing the dependence of system performance on system design and component properties.

Interlaboratory Comparisons. A simple way to analyze the discrepancies between different testing laboratories presumably employing the same test procedures was recently worked out. The method makes use of a graphical presentation of the test data which allows each laboratory to tell at a glance how its performance compares with that of others. The graph can point the way to corrective action to eliminate the bias, if any, in the technique used by a particular laboratory; or it may indicate the need for an improved test procedure—one that lends itself better to uniform application by all laboratories. A method for analysis has been worked out to provide numerical estimates of the parameters of the test procedures including an estimate of the precision of the test procedure. This procedure has been



Statistical design for diagnosing discrepancies in results from different testing laboratories (page 95).

successfully used in intercomparing the results of industrial, State, and Government laboratories for tests of paint, soap, and other materials such as paper (see sec. 2.7, p. 65).

Statistical Services. Statistical services were rendered to the U.S. Geological Survey on the formulation of a mathematical model for the analysis of hydrologic data. For the Veterans' Administration, the Naval Ordnance Laboratory, and other laboratories, a number of large-scale analyses of data were programed and run on the Bureau's computer. Typical of the computing service provided for other sections of the Bureau is the program prepared for the machine computation of data from mechanical and interferometric measurements of gage blocks. A statistical analysis to provide data on the precision of the measurements and internal checks to assure the absence of systematic errors was also carried out.

Mathematical Physics. To aid in the formulation of mathematical theories basic to the development of theoretical physics and engineering science, the Bureau, with the support of the Office of Scientific Research, USAF, conducts a program devoted to problems of this type. Studies during the past year included an analysis of the important problem of the

mechanics of turbulent diffusion by the techniques of statistical mechanics, and analysis of the outflow from a breached dam for the Army Map Service. A statistical approach was also applied in studying the kinetic equation for a plasma. A survey and outline of problems in plasma dynamics and magnetohydrodynamics form the basis for planning expanded research in these fields.

Other work included a determination of the fluctuations in the annual flows and runoffs of rivers, investigations of the behavior of the solutions of the first-order nonlinear Poincaré equation and the second-order nonlinear Rayleigh equation, a study of thermodynamics and hydrodynamics of two-phase flows, and a promising theoretical investigation of satellite motion.

2.12. Data-Processing Systems

The Bureau's program in data-processing systems includes research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. The Bureau serves the Government as a central agency for providing comprehensive and readily available information in both the development and application of high-speed automatic data-processing systems. As a result, a great number of requests are received from other government agencies for assistance and advice relative to their data-processing problems in engineering, management, and operations research, as well as control systems and simulation. These advisory activities strengthen the Bureau's basic computer program, which ranges from research in components, circuits, systems, and simulation to advanced work in new computer applications.

Among the accomplishments in this area during the past year were basic and applied research on components and circuits for use in analog and digital data-processing devices and systems, advancement of the theoretical formulation of basic principles and logical techniques for designing large-scale systems, and special studies of the application of such systems to government problems. In cooperation with the National Science Foundation, an information center and advisory service on research and development in the field of information processing and retrieval was established.

SEAC and Analog Computing Facilities. SEAC has continued to be used as the Bureau's high-speed digital research facility. It assisted in investigations of simulation techniques, patent search trials, picture processing, pattern recognition, and data format conversion. In some instances, processing these problems resulted in modifications that improved the utility of the machine. For example, the input-output system was modified to accept a 36-bit word as well as the usual 45-bit word so that data recorded on the magnetic tape units of a commercial computer could be read into SEAC and then read out on a display oscilloscope or on an analog plotter. A new input-output order was also incorporated so that any number of words, from 1 to 2,048, may be read into or printed out from the memory with a single command.

The problem-solving capability of the Bureau's analog computer was extended by incorporation of an additional three-product multiplier unit and a servo resolver. A point-plot system was added to the 30 by 30 in. X–Y plotter, and a set of 0.1 percent resistors and capacitors were procured to permit more precise calibration of operations.

The Bureau's simulation facility, which includes use of both SEAC and the analog computer, was used to simulate automatic intercept vectoring systems and proposed methods for control of takeoff and landing traffic at the Washington National Airport.

Initial surveys of laboratory operations throughout the Bureau led to the identification of at least 50 areas in which the recording and processing of experimental data could be automated. Typical problems encountered include atomic scatter, electron resonance, thermodynamic theory, surge voltage, transistor circuitry, Fourier analysis, X-ray spectra of alloys, lens image patterns, transistor aging tests, Civil Service Board records, spectral reflectance of glasses, calibration of thermocouples, and weighing techniques. Continuing consultation and assistance on procedures for collecting, converting and transmitting data for automatic high-speed computation also resulted in the design of several pieces of special data-logging equipment.

PILOT Data Processor. Because of the anticipated variety of potential applications, the new NBS Pilot Data Processing System has been designed to incorporate into a single installation such characteristics as high data-handling rate, flexibility of communication with external devices, and a wide repertoire of internal processing operations. During the past year, the logical plans for the entire PILOT system were transcribed into a form suitable for processing on a high-speed computer to convert them into wiring tables describing the point-to-point electrical interconnections. The input data, punched on more than 20,000 cards, were subjected to detailed checking and processing, using the computer programs developed as part of the digital systems research program to produce the required tables.

The physical structure of the central part of PILOT is nearing completion. The rapid-access diode-capacitor primary and secondary memory units have been completed except for a full complement of storage elements. The central computing and control units of PILOT, including the diode-capacitor memories, will contain more than 6,100 vacuum tubes and 193,000 diodes.

Components and Techniques. Basic research in the development of new computer components through the novel use of materials and physical phenomena is expected to result in greatly improved computer performance in the "next generation" of data-processing equipment. Because there is an immediate need for large random-access memories with read-write cycles of less than 1 microsecond, an investigation was made for the Department of the Army of thin ferromagnetic films as basic storage elements. Special equipment was obtained for better control of the characteristics of the experimental films, and a hysteresis loop tracing oscilloscope was designed and constructed. Studies are in progress on evaporation techniques for producing multilayer devices.

Left: **Analog-digital simulator used to study air traffic problems. An airways map of the Washington, D.C., airport appears on the screen.** ***Right:*** **Prototype high-speed document retrieval device handles microfilm at the rate of 2,400 pages of documents per minute (pages 98, 100).**

Progress in circuit techniques was made by developing a set of seven compatible transistor switching circuits in a program sponsored by the Department of Defense. These circuits can be utilized as building blocks in assembling various data preparation and recording systems for input to large-scale digital data-processing systems. The design of these circuits was greatly facilitated by deriving the equivalent circuit that directly characterizes a transistor in such a way that its performance in a switching circuit can be accurately predicted either by digital computation or by analog simulation. It differs from previous equivalent circuits primarily by representing the input impedance as well as the transfer ratio even in the condition of saturation.

Cloud Height Data Analyzer. A special application of these transistorized circuits was made for the U.S. Weather Bureau in the redesign of the rotating beam ceilometer. The new circuit design utilizes these transistorized logical building blocks to perform the automatic control and preparation of weather data for transmission. A prototype of the equipment was provided for evaluation of both the new technique and component reliability for future use at the Weather Bureau's automatic (unattended) weather stations.

Digital Circuitry. The transistor-magnetic core circuitry designed to perform the logical and switching functions of the central part of a high-speed digital computer was subjected to a thorough theoretical analysis in a program sponsored by the Department of the Army. The gain, stability, and volt-second transfer function of a single stage have been determined. A successful method for connecting such synchronous circuits to asynchronous magnetic tape recording units and pulse generators was also achieved.

Document Retrieval Device. The rapid selector, developed for the Navy Bureau of Ships and the Patent Office, is a machine that rapidly retrieves information from massive files or documents that have been recorded on 35-mm film. The logic and control circuits have now been completely transistorized and the film transport and optical system have been improved. A new film transport, now being designed, is expected to increase the film speed to 20 feet per second to improve the handling of the master film, and to simplify the overall operation.

Packaged Computer Circuitry. Standardized basic building blocks in the form of plug-in packages with which complex digital computing and control circuits can be assembled were developed under the sponsorship of Air Force Cambridge Research Laboratory. In addition to the two central computer types (regenerative pulse amplifier, diode gate, neon indicator driver, and switch signal filter boards), several special-purpose packages necessary for a complete digital system were designed, tested and converted to finished printed circuit form: A master clock oscillator, a constant amplitude clock driver, a transistorized plugboard driver and a plugboard mixer. An assembly of more than 200 interconnected packages was tested for operational margins, crosstalk, ground noise, and filtering. The effectiveness of twisted pairs and of a good ground plane was demonstrated. Dynamic and static package testers were also designed and developed.

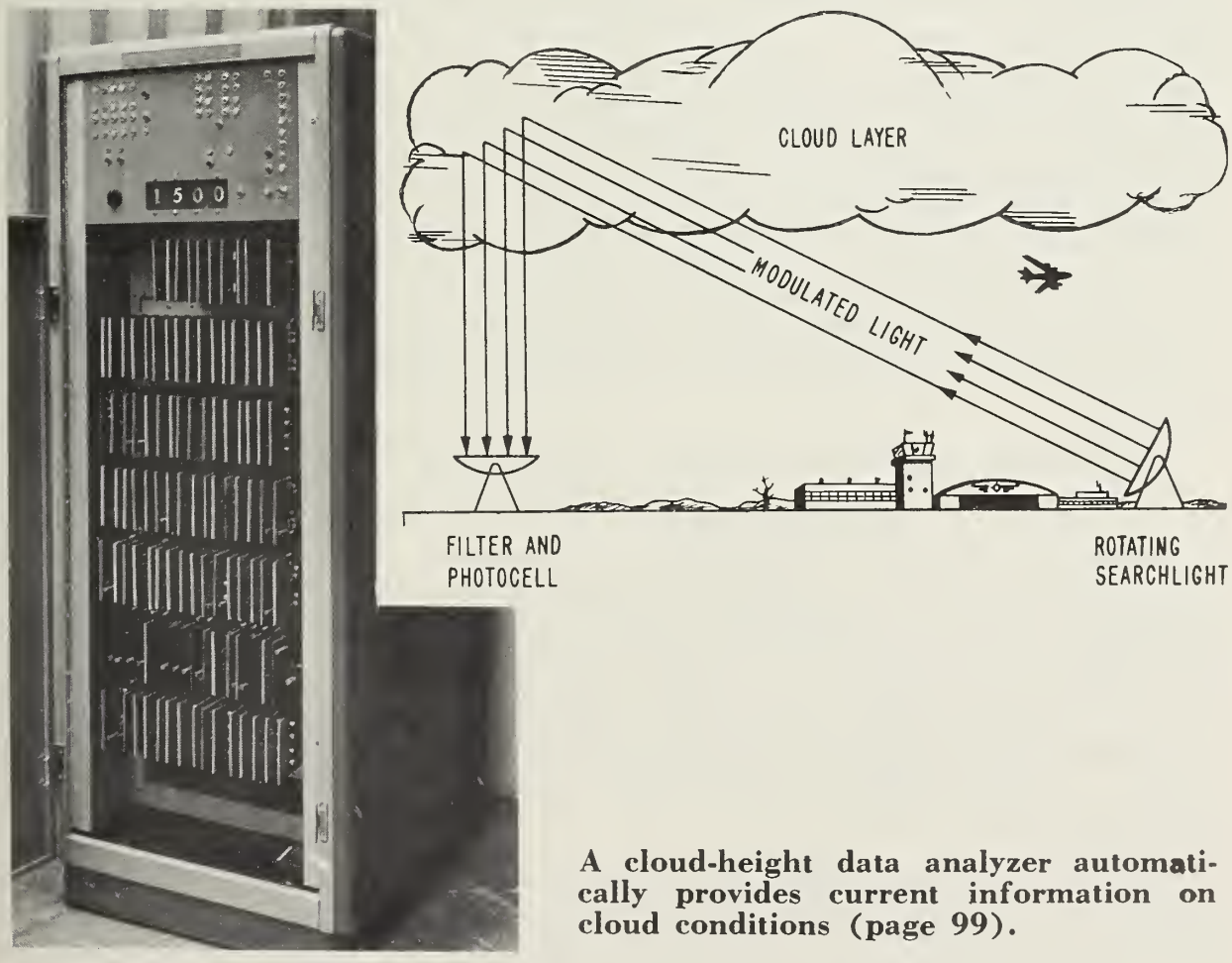
Digital Systems Research. A new way of using incidence matrix techniques for analyzing complex logical problems was discovered in an investigation for the National Science Foundation. These problems are encountered when groups of concurrently operating computers, or other automatic devices, are harnessed together to form an intercommunicating network. In such a network, keeping the separate programs on the various computers efficiently in step with each other is important. Special techniques are needed for analyzing the complex priority relationships between related steps in the individual programs. Using incidence matrix techniques, new methods have been found for automatically detecting and correcting possible conflicts in priority between the different machines and for deriving optimal sequencing schemes in writing programs for them.

Flight-Maneuver Data Processing. A joint U.S. Air Force-Navy-National Aeronautics and Space Administration program has been set up to consider establishing a data-processing facility capable of processing a minimum of 30,000 flight-hours each year of maneuver-loads data from aircraft. Accelerations, velocities, and other parameters are to be analyzed to determine the effects of maneuvers on structural loading of aircraft. Under the sponsorship of the Navy Bureau of Aeronautics, the Bureau studied the computing techniques and equipment that would be required for such a facility. Several possible operating systems, varying from all-digital to combined analog-digital processing, with several variations dependent on the degree of automation, were proposed for consideration. Since for any facility a high-speed digital computer is required, capabilities of various

available computers were studied and sample computations programed to estimate computing speeds.

Automatic Processing of Electrocardiograph Data. At the request of the Veterans' Administration, a prototype research device that uses automatic data-processing techniques to handle electrocardiograph data was developed. This equipment accepts data about the electrical activity of the heart from analog magnetic tape, converts it into numerical information, and then rerecords it onto digital magnetic tape for input to a high-speed computer for final processing. An experimental computer program was written to test the feasibility of the complete computer data handling procedure before the full-scale processing task began.

Automatic Mail-Sorting Developments. The Bureau is continuing to assist the Post Office Department's Research and Development Division in its objective of applying automatic equipment and data-handling techniques to the improvement of the mail-handling operation. A detailed analysis of various configurations of automatic sorting machinery was undertaken to relate such parameters as mail input and output rates, sorting rates, destination handling capacities and cost per unit. Incoming and outgoing distributions of mail at several large city post offices were studied and analyzed, and system studies were made to evaluate methods for the three basic kinds of sorting—outgoing, incoming, and carrier-walk. Several studies were also made concerning the requirements for a memory system or an electronic directory for use with sorting equipment.



A cloud-height data analyzer automatically provides current information on cloud conditions (page 99).

Computer Data Editing and Reporting. The U.S. Public Housing Authority must constantly review a tremendous volume of reports of eligibility for continued occupancy of low-rent housing. The Bureau has been studying the possibility that the analysis of this data can be automated. As a result, computer programs that edit the data automatically, compile statistical tables, and generate form letters were developed for preliminary trials. Query data were processed and machine-prepared letters were composed by the computer program and run off on the output printer. Similar edit, report generation and statistical analysis routines for the housing applications reports are now planned by the PHA.

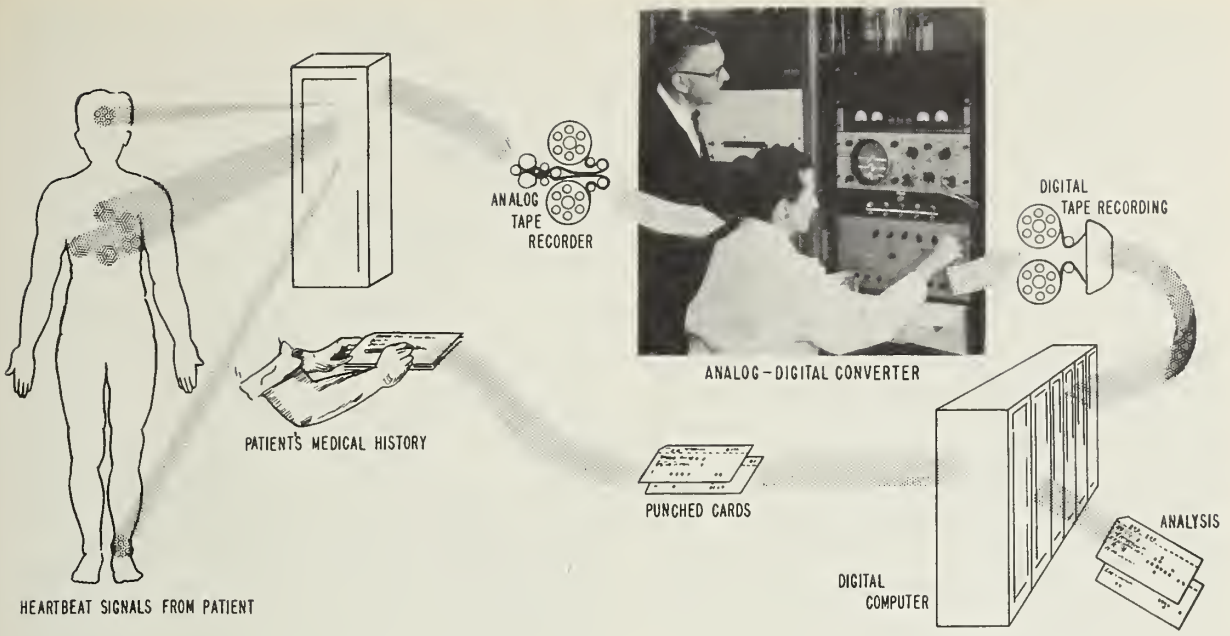
Mechanization of Patent Searching. Progress has been made in a cooperative program with the Patent Office for the mechanization of patent search operations. A comprehensive machine-search procedure, for examining patents on the chemical arts, was revised and expanded to include such complex operations as specific and generic searching as well as "negative statement" searching. The program makes use of a multiplicity of mutually exclusive search paths, the principal ones of which have been tested on SEAC by using samples of question and disclosure data.

Studies were carried out on the feasibility of searching English-language texts by machine for specific information and on artificial dialects of increasing sophistication for use in retrieval experiments. A program was written for processing and analyzing pictures, and boundary tracing schemes were investigated.

Research Information Center. Since the activation of the Research Information Center and Advisory Service on Information Processing, under the sponsorship of the National Science Foundation, major emphasis has been on collecting and organizing literature pertinent to the field and formulating a comprehensive bibliography covering a wide range of interests in information storage, selection, and retrieval. A field glossary, consisting of defined terms selected from the vocabularies of the various allied disciplines, is being tabulated; lists of research workers in the field are being compiled; and a study of the related basic research areas is in progress to determine which techniques seem likely to be applicable to the solution of problems in the field.

Additional Data-Processing Applications. The monthly reports of the Federal Home Loan Bank Board serve as one index of the status of the Nation's economy. Assistance was requested in analyzing the Board's operations and for a feasibility study on the applicability of automatic data-processing techniques to speed up the preparation of the reports and minimize delays in subsequent actions. Initially, methods to test consistency of the input data and to estimate substitution data were undertaken. Processing of actual data to produce the required reports was subsequently demonstrated.

At the request of the Federal Communications Commission, a preliminary study of the possibility of speeding up the flow of information for management decision making was undertaken. The task was to identify those areas



An analog-to-digital converter was developed for changing heartbeat data to a form suitable for use in a high-speed computer. ***Inset:*** **A technician selects a suitable cardiac complex by monitoring signals on oscilloscope (page 101).**

of their activities where automatic data processing techniques would be applied. A joint cooperative program to study the data-flow pattern and the procedural activity of each functional area was then undertaken to establish the basic requirements of a data-processing system.

At the request of the General Services Administration, assistance was provided in the evaluation of proposals for an automatic data-processing system to integrate control over the Federal Supply Services network of stores depots.

A program for personnel data recording and reporting, requiring the development of file maintenance routines that can be used for generalized updating of "personality type" files, has been inaugurated, and preliminary computing machine routines have been programed. As a first example of a report generation program, sample personnel records of NBS have been selected, encoded, and converted to tape. The major part of the coding for the generation of the Bureau's portion of Monthly Report of Federal Civilian Employment has been completed.

2.13. Cryogenic Engineering

The Bureau's cryogenic engineering activities, centralized at the Boulder Laboratories, are designed to provide information on the behavior of systems at very low temperatures. Both Government and industry are faced with problems in this rapidly growing, specialized field. One difficulty encountered is the critical nature that the properties of materials sometimes assume at low temperatures. To solve this problem, the Bureau provides basic materials data at cryogenic temperatures as one of its main activities. Equally important are other Bureau research programs concentrated on insulating techniques, liquid flow, and instrumentation.

Rendering advisory services to both industry and other government agencies is another intrinsic part of the Bureau's efforts to help establish the field of cryogenic engineering. The demand for such help has greatly increased as a result of accelerated programs dealing with long-range missiles and space vehicles which rely on cryogenic liquids as propellants.

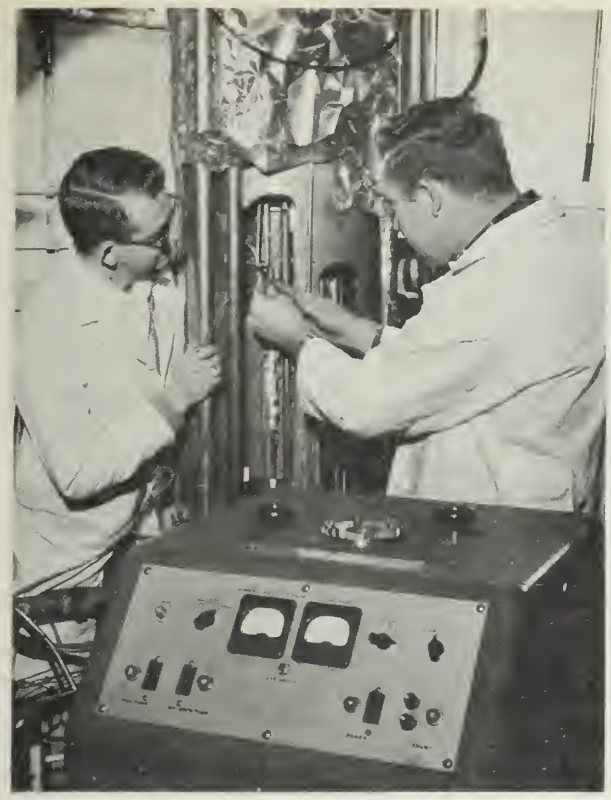
Low-Temperature Properties of Materials. Property measurements at low temperatures are usually made to determine the suitability of a material for a specific application. Another area where properties and the effects of temperature are important is the field of thermometry where thermocouples are often subject to errors due to heat conduction. To help improve temperature measurements, the Bureau measured to 4° K the thermal conductivity of a gold-cobalt alloy that is widely used in low-temperature thermocouples. The present results permit users to estimate the extent of the errors introduced.

Data to be directly applied in cryogenic engineering were obtained on the strength and thermal efficiency of 5086 aluminum alloy. Results confirm that this alloy can be successfully used in welded structures at very low temperatures. Other investigations were made on organic adhesives, important where welding and soldering are ruled out by the nature of the application or the materials to be bonded. Ten organic adhesives were studied down to 20° K for the Wright Air Development Center. The adherend was aluminum or stainless steel. High strengths independent of temperature were obtained with an epoxy-phenolic adhesive supported on glass cloth. A filled epoxy also behaved well in conformance with earlier work.

The temperature conditions under which martensite can form in 300 series stainless steels were studied. Types 303 and 304 were found to be strongly transformed. This transformation is promoted by thermal cycling to low temperatures. A sample of type 304 continued to transform slowly after nearly a year of daily cycling between ambient and 76° K. The effect of this transformation on strength will be determined. Although the martensite phase is known to be very brittle, preliminary results indicate that partially transformed 304 retains substantial toughness.

Insulation. The most striking development of the past year was the discovery of new evacuated laminates that give tenfold improvement in insulating value over the best evacuated powders. An effective mean thermal conductivity of 0.5 microwatt/cm-deg K between boundary temperatures of ambient and 20° K has been attained. The laminates consist of alternate layers of aluminum foil and thin glass-fiber batt or paper. Development of practical insulating schemes based on these laminates will permit revolutionary simplification and compactness of large vessels for liquid hydrogen or helium.

The use of uninsulated equipment for the transfer of liquid hydrogen was shown to be desirable for high-flow-rate applications. The heat transfer to, and the pressure drop in, such systems were measured. The Bureau also demonstrated that the use of condensing-type vacuum insulation in equip-



Studies of the behavior of liquid oxygen (boiling in large tank at right) provide information needed for the design and launching of large rockets which use liquid oxygen as a propellant. *Left:* Distillation column used in the separation of hydrogen isotopes. The distillation technique promises to make possible economical large-scale production techniques for obtaining deuterium (pages 106, 104).

ment which is to have the vacuum space sealed off provides insurance against the disastrous effects of small leaks. This desirable effect stems from the sorbtive capacity of solid CO_2 for H_2 gas.

Liquefied Gas Flow. Basic information on the transfer of liquefied gases is essential to the design of piping systems for two-phase fluid flows. The Bureau therefore investigated the adiabatic and highly diabatic flows of fluorotrichloromethane (CCl_3F commonly known as Refrigerent F–11) and hydrogen. The results indicate the Lockhart and Martinelli correlation, with a simple momentum correction, can be used to predict the pressure drop in two-phase, single-component fluid flow.

Venturis, orifices, and turbine-type meters all proved to be reliable in measuring the flow of liquid hydrogen. Accuracies of better than 1 percent were obtained.

Cryogenic Equipment. An air-transportable, 50-gal liquid-oxygen, aircraft-servicing Dewar, designed by the Bureau for the Wright Air Development Center, was completed. The steady state heat leak is only one-fifth that present in currently used equipment. The major sources of heat leak—supports and piping—in other equipment cause only negligible heat leak in the optimized container. Innovations such as synthetic-fiber webbing supports and utilization of the load-bearing properties of insulating powders were found practical.

Assistance to the University of California's Lawrence Radiation Laboratory on the cryogenic engineering of liquid hydrogen bubble chambers was

continued under the sponsorship of the Atomic Energy Commission. Efforts were highlighted this past year by the successful operation of a chamber 72 inches long containing about 550 liters of liquid. The hydrogen refrigeration system designed by the Bureau provided continuous refrigeration and the necessary automatic temperature control of the chamber liquid.

Activities in the cryogenic engineering of bubble chamber and associated refrigeration systems have led to many requests for advice on design details. As part of the resulting program of assistance, the Bureau will cooperate with the British National Bubble Chamber group in designing cryogenic systems next year.

Ortho-Para Conversion of Hydrogen. An important research program covering all aspects of the conversion of hydrogen from the ortho to the para form was brought to a successful conclusion during the past year. The primary objective of the work was the development of catalysts for promoting the ortho to para reaction. The development of a highly effective catalyst which makes possible the manufacture of stable liquid parahydrogen rather than the unstable liquid normal hydrogen has resulted in a substantial reduction in storage equipment costs.

Processes, such as film and pore diffusion, which determine the kinetics of the reaction, have been studied. Progress was made in determining the controlling step in the reaction rate. In addition to the kinetics work, a study was made of activation procedure.

Hydrogen Distillation. Cryogenic distillation of hydrogen has long been recognized as an excellent method for deuterium recovery. Because of the wide uses predicted for deuterium and heavy water, economical large-scale production techniques for obtaining this isotope are in demand.

Unloading liquid helium flown 1,700 miles from Denver to Washington. Over 90 air trips have been made to supply the Bureau's Washington laboratories with helium liquefied at the Boulder (Colo.) Laboratories (page 108).

Low-temperature data on the compression deformation of indium were obtained prior to its use to seal the massive glass window of the 72-inch liquid hydrogen bubble chamber for the University of California (page 105).

A program of studies on deuterium separation included the operation and evaluation of a hydrogen distillation pilot plant. Parameters such as plate efficiency, plate geometry, pressure drop, and heat transfer were considered and the data obtained are expected to provide a sound basis for the design of full scale industrial plants.

Cryogenic Engineering Data. The Cryogenic Data Center, established last year, has indexed several thousand listings of published articles and reprints, useful in the cryogenic engineering field. Bibliography service is being furnished the NBS staff on request, and reports or photocopies of material are procured when needed. Plans are being formulated to extend this reference service to the cryogenic engineering industry as a whole.

Another activity of the Cryogenic Data Center is the compilation of the thermophysical properties of cryogenic materials and the assembling of data sheets, references, and other pertinent material, into an expandable compendium. This project, sponsored by the Wright Air Development Center, started last year and is expected to be completed early in 1960.

A book by a member of the cryogenic engineering staff ("Cryogenic Engineering", by R. B. Scott, D. Van Nostrand Co., 1959) makes readily available to engineers and other research workers the specialized techniques of cryogenics as well as a considerable amount of frequently used data.

Helium Properties. Thermodynamic properties of helium in the compressed-liquid region were obtained from all known sources and assembled into several properties charts. Some very recent data in the compressed

liquid region were examined and correlated with earlier data. The resulting correlations were believed to represent the best information currently available and should prove extremely valuable to the cryogenic design engineer.

Gas Liquefaction. Production of liquefied gases this year continued to increase. Approximately 280,000 liters of liquid parahydrogen (a 30-percent increase over last year), and over 1,200,000 liters of liquid nitrogen were produced. Recovery of evaporated hydrogen gas from liquid storage and tests netted over 5 million cubic feet for reliquefaction.

The production of liquid helium this year nearly doubled that of last year. Forty-eight hundred liters were produced and almost half was shipped by air to the NBS Washington Laboratories, mostly for use in the Free Radicals Research Program (see sec. 2.3). The helium liquefier which had been installed as an integral part of the hydrogen liquefier system was revamped and made independent of the hydrogen plant so that it could be operated simultaneously.

2.14. Radio Propagation

The Central Radio Propagation Laboratory has the primary responsibility within the U.S. Government for collecting, analyzing, and disseminating information on the propagation of radio waves at all frequencies along the surface of the earth, through the atmosphere, and in outer space. To carry out its responsibility, this Laboratory conducts research on the nature of radio waves and the media through which they are transmitted, the interaction of the waves with the media, and the nature of radio noise and interference effects. A network of field stations is operated from the Arctic to the tropics, and data are exchanged with other laboratories throughout the world. The work of the Laboratory is divided into three areas: radio propagation physics, radio propagation engineering, and radio communications and systems.

Radio Propagation Physics

The radio propagation physics program is directed toward a better understanding of the interaction of radio waves with ionized media, such as the earth's ionosphere and interplanetary space, and the practical problems of communication via these media. To achieve these objectives, the program includes: (1) Basic research on the composition, physical processes, and structure of the upper atmosphere and interplanetary space, on the formation and variation of the ionized state of these regions, and on the interaction of radio waves with the ionization; (2) study of the reflection, refraction, scattering, and guided-mode mechanisms by which radio waves are propagated through the ionosphere and interplanetary space; and (3) regular public service by predicting long-term changes in useful frequencies for communication, the short-term warning of disturbances to communication, and by collecting and distributing ionospheric and solar data on a national and international basis.

Electron Density Measured Directly. Radio propagation parameters, useful in communication applications, come directly and fairly accurately from measurements of echo heights by soundings with 1- to 25-Mc radio-wave pulses. However, the production, depletion, and dynamics of the ionospheric layers can be understood only if the electron density is known at each height. In addition, with scientific and technological interest in space, it is important to learn more about the ionosphere above the level of peak ionization of the *F*-region, the limit of conventional radio probings.

The Bureau's experiments with scatter radar have shown that, for the first time, direct measurements can be made of electron density throughout the ionosphere. Also, the Bureau's computing facilities were used for the first large quantity calculation of electron density profiles from conventional ionospheric soundings. On the basis of theoretical work, these profiles have been extrapolated above the peak density of the *F*-region to 1,000 km or more.

Electron Densities Measured to 750 Kilometers. Radio waves are very strongly reflected from the ionosphere when they meet electrons having a plasma frequency equal to the frequency of the probing radio wave. Radio waves of higher frequencies penetrate outer space, but a minute fraction of this energy is scattered by free electrons. W. E. Gordon of Cornell recently showed that this extremely weak scattered energy should be proportional to the electron density at the place the scattering occurs. This prediction was borne out by an experiment performed at a Bureau field station (Long Branch, Ill.).

For the first time a vertical profile was obtained of electron density through the entire ionosphere by a direct experiment with ground equipment. The profile extends from the lower *E*-region through the peak density of the *F*-region and beyond, up to 750 km. It is possible to extend the method to give improved height resolution and an extended height range of approximately 3,000 km.

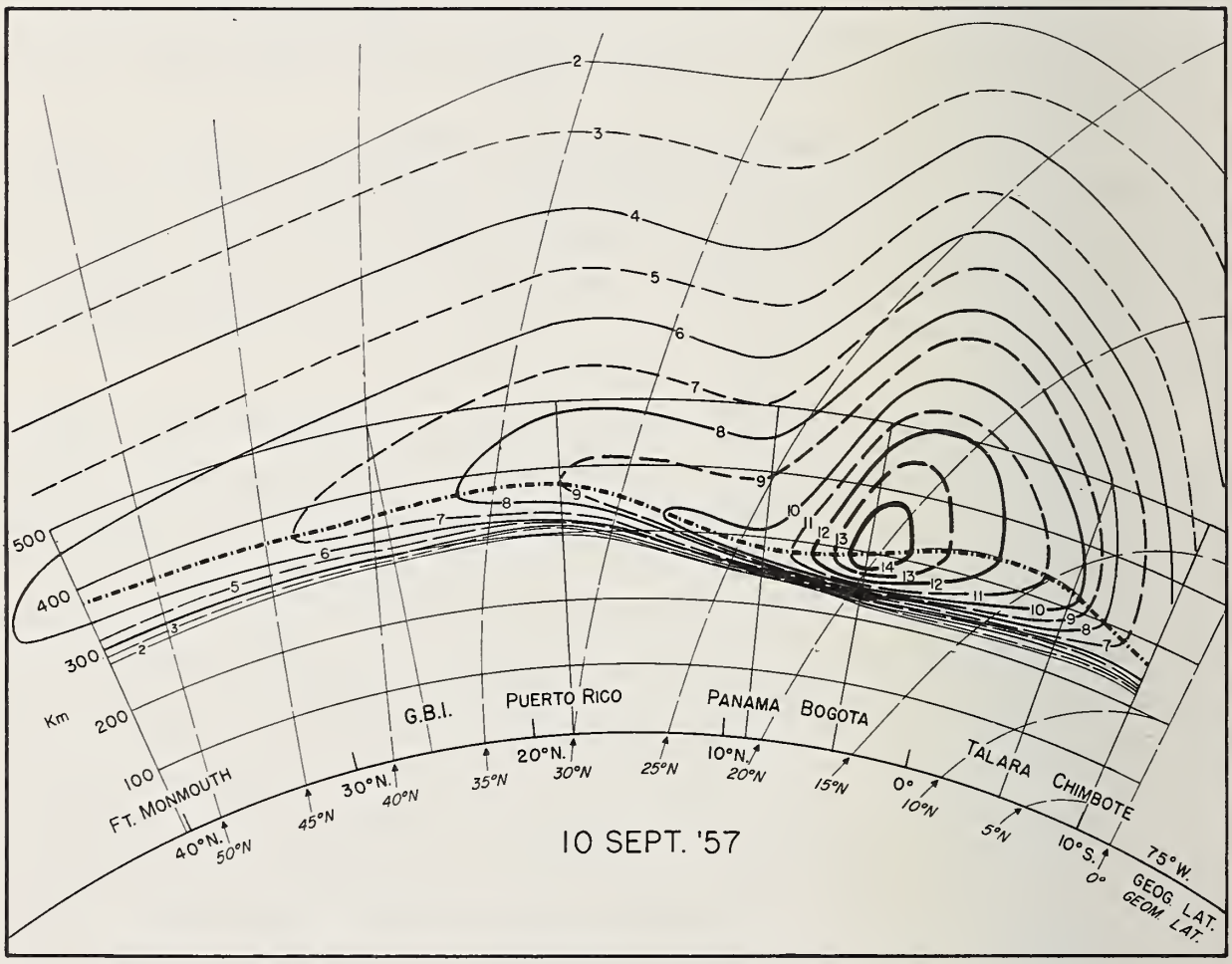
In one experiment, a 4-acre broadside antenna was connected with a high-powered 40-Mc pulse transmitter rated at 6 million watts peak power. With these components and the transmitter unavoidably operating at 10-percent efficiency, this improvised radar had sufficient sensitivity to detect the incoherent scatter signals. A later experiment gave better detail. The scatter signal was positively identified, and the Doppler broadening of the returned echo was found to be much less than predicted by Gordon. The Bureau's theoretical explanation is that the scattering is from a statistical assembly of electrons rather than from individual free electrons scattering independently. The scatter radar technique has further possibilities for physical research on the ionosphere and exosphere, as well as for application to long-range communications.

True Ionospheric Reflection Heights Recovered. When high-frequency radio waves are used to probe the ionosphere, their group velocity varies with the electron density along the ray path and according to the

earth's magnetic field. Thus the echo heights from conventional ionospheric soundings are virtual heights, and the true heights of reflection can be recovered only by rather involved calculations.

True reflection heights can now be recovered in quantity by electronic computer at the Bureau's Boulder Laboratories. However, it is practical to analyze so completely only a very small fraction of the soundings available. (The IGY rate was 5 million soundings annually at NBS-associated stations, 15 million annually throughout the world.) Many thousands of profiles have been calculated for use in ionospheric research and for determining refraction errors that occur in radio tracking of satellites, space probes, and other high-altitude vehicles traveling in or above the ionosphere. The Bureau's facilities are also beginning to be used systematically to develop data on the "climatology" of the ionosphere.

Exosphere Approximated. Except for isolated and limited experiments by scatter radar, whistler, rocket, and satellite techniques, there is detailed knowledge of the ionosphere only to the height of the peak electron density of the *F*-region, which is 200 to 500 km depending on time, location, and other factors. The Bureau has computed profiles up to the *F*-region peak, and systematically extrapolated these values to exosphere heights according to a model for the upper *F*-region which agrees very well with the



Ionospheric section along 75th west meridian, showing plasma frequencies calculated from ground-based soundings made at NBS-associated field stations. Contours at greater heights fit a theoretical model of the high ionosphere (page 109).

few existing observations. At these levels in the atmosphere, ion production is negligible and gases are effectively in diffusive equilibrium. From this work has come an outer ionosphere approximation that can be applied wherever ground-based soundings are made. This approximation is proving valuable for space applications.

Upper F-region Investigation Planned. The upper *F*-region will be investigated by satellite techniques, either directly by probes or indirectly by radio soundings from above the ionosphere. The Bureau made a scientific and engineering feasibility study for the National Aeronautics and Space Administration, as the necessary first step toward topside sounding experiments.

World Maps of the Ionosphere Issued. For measuring ionospheric characteristics, a network of observing stations is maintained by many countries. A major objective of this network is the development of an optimum global representation of the ionosphere for use in long-distance communications and similar applications. Until such a representation is available, ionosphere predictions must be made by interim methods.

The Bureau issued 222 world maps that make up the first portion of a semipermanent representation of average propagation characteristics of the *F*-region. These maps based on data from the world network give characteristics for alternate hours, Universal Time, and for 6 months slected to be representative of annual variations.

The two principal propagation characteristics are given for sunspot number of 50. World contours of the dependence on sunspot number are also included. These maps fill a need for basic ionospheric data used in planning radio communication systems. They probably represent the utilmate in treating ionospheric data for this purpose (by hand and graphical techniques) for the pre-IGY world network of observing stations.

Ionosphere Mapped by Computer. A solution has been found for the general problem of making worldwide maps of the ionosphere by use of numerical analysis and large-scale, high-speed computers. The work has emphasized the global representation of ionospheric characteristics and their many variations with time. Problems included in this work have some similarity to those encountered in synoptic meteorology. Rigorous mathematics are applied to ionospheric data, taking into account their statistical "noise".

The first part of the problem is a three-dimensional representation of the data for a given month. Specialized routines are used on a high-speed computer, and solutions are furnished for a number of applications. In one routine, a "contour map" (at any desired instant of Universal Time) is traced automatically on a digital plotting machine making direct use of the computer output. This method has been applied to 4 months of 1957: March, June, September, and December; typical of the four seasons. As far as can be seen, the maps are at least as good as those produced by hand methods, and are free from subjective errors.

Further steps are being taken toward a satisfactory method of prediction. Two new dimensions are required to analyze the long-term time series: seasonal periodicity and solar activity variations. There are basic difficulties because the available time series are nonstationary and relatively short. Therefore, standard statistical methods for time series are not directly applicable.

Efficient Propagation Mode Discovered in Pacific. In the course of an IGY project for measuring the difference in the effectiveness of sporadic–*E* at 100 km, a propagation mode of comparable efficiency was found to be active regularly during the evening hours of equinoctial months for an experimental path in the western Pacific. In September 1958, a special expedition produced evidence that this is an *F*-region scatter mode, but that it is many times more efficient than scatter propagation via the *F*-region observed in other parts of the world. Early results of these sporadic–*E* experiments show that this propagation mode occurs about three times as often on the western Pacific radio path as on a control path in the Caribbean. Further analyses and experiments will be needed to tell if there is a real geographic difference in the atmosphere or if unsuspected geomagnetic influences are involved.

Studies of signal fading rates have shown new evidence that sporadic–*E* is produced by inhomogeneities in the electron density distribution in the *E*-region rather than by a thin horizontal layer having a relatively high electron density. These studies were based on experimental paths within the United States.

Airglow and Aurora Origin Questioned. The statistics of radiations (5577A) from the upper atmosphere observed at Thule, Greenland, were compared with similar data from low-latitude stations. The results suggest that the faint aurora and night airglow have a common origin. This is contrary to the general opinion that these phenomena arise from separate and distinct physical processes in the upper atmosphere. Another potentially significant result is coming from NBS monochromatic observations of the aurora made at Fritz Peak and Rapid City during the IGY. Evidence of a distinct auroral fringe was found on the equatorial side of the main auroral zone. This fringe seems to precede intense auroral activity. Explanation of this phenomenon would require significant modification of conventional auroral theory.

Scattering Phenomena in the Equatorial Ionosphere. During an IGY transequatorial experiment, evidence was produced that a type of spread echo from the *F*-region (often observed in the equatorial region by conventional ionospheric soundings) is caused by an intervening thin layer of ionization irregularities. These irregularities were found to be about 15 meters or less, considerably smaller than suspected. They were shown to be alined with the earth's magnetic field, an important consideration for their use in communication systems. Scattering in the equatorial *E*-region is confined to a latitude belt 10 to 12 degrees wide, with stronger effects to the south than to the north of the magnetic equator. These phenomena are closely related

to the electrojet currents flowing in the ionosphere above the magnetic equator and have promising communication possibilities.

Ionosphere Measured by Satellite Signals. A detailed analysis of 20- and 40-Mc signals (from satellite beacon transmitters) indicated that the Faraday rotation method can give the electron content of a column of ionosphere within a few percent. The same analysis showed that there are large-scale irregularities in electron content amounting to roughly 2 percent during a single satellite pass. The indicated spatial dimensions of these irregularities are 100 to 500 km. Observations of satellite signals also give information on the sharpness of the focusing of radio waves from the ionosphere at the edge of the skip zone.

Whistlers' Direction Demonstrated. Atmospheric whistlers are guided along the lines of force of the earth's magnetic field from the point of the generating lightning discharge outward into the exosphere and back to earth in the opposite hemisphere, according to present theory. Many observations at the Bureau and elsewhere have supported the general outlines of this theory. The first observations of the direction of arrival of whistlers were made at the Bureau in June 1959, and it was demonstrated that many whistlers come from discrete directions. The experiment has not progressed sufficiently to specify the angles.

Data Center Maintained for Ionosphere and Airglow. Under the IGY program, observational data are collected in World Data Centers to be generally available for research. According to the international plan there are three or four duplicate centers for each IGY discipline, located in various parts of the world. World Data Center A is in the United States and the subcenter for ionosphere and airglow data is at the NBS Boulder Laboratories. The flow of data is about two-thirds complete, and many millions of observations are cataloged. An increasing number of scientists from the United States and abroad are making use of the Data Center. Together with the Bureau's library of data collected previously, this is probably the fullest collection of ionospheric and airglow data anywhere in the world.

Radio Propagation Engineering

More efficient use of the radiofrequency spectrum is the aim of the Bureau's program in radio propagation engineering. This objective requires a basic understanding of radio-wave propagation, noise, and interference. To this end, statistical samples of data on radio-wave propagation and radio noise are collected so that the underlying phenomena may be accurately described. Methods are developed for using these samples to predict the statistical characteristics of propagation and noise variables required in engineering applications.

In general, the program may be divided into four areas of investigation: tropospheric propogation, VLF propagation, radio noise, and terminal equipment. Substantial progress was made in each of these areas during the year.

Radiofrequency Transmission Loss Predictions Improved. The strength and fading properties of a tropospheric signal are determined by terrain irregularities, climate, and weather. These properties must be estimated in designing and allocating communication, broadcasting, and navigational facilities.

Until recently, distances beyond the horizon of a radio transmitting antenna were considered useless for frequencies above 100 Mc. Further improvements to a formula for predicting the cumulative distribution of tropospheric transmission loss indicate a possible solution to this problem. The formula can be used for any combination of terminal height or gain, for frequencies from 50 to 100,000 Mc, for any geographical location or terrain profile, and for propagation distances from 0 to 1,000 miles.

A method was developed for determining the transmission loss for very closely spaced antennas. This method may be useful in assessing the interference between several radio systems operating from a common base.

High-speed electronic computers improve speed and accuracy in the preparation of world-wide ionospheric maps (page 111).

Further improvements were made to methods for predicting the tropospheric bending of radio waves in terms of the radio refractive index at the surface of the earth. These methods are expected to be applicable to improving radar direction finding and to radio missile or satellite guidance systems.

Radio Refractive Index Mapped. World climatological maps of the surface radio refractive index were prepared. On these maps, climatic regions are distinguished by their differences in mean level and by the annual range of the surface refractive index. Correlation studies were made between bending, elevation angle error, and the surface value of the radio refractive index. These studies led to a statistical method for predicting refraction effects which agrees well (for initial elevation angles of the ray of 1 deg or more) with predictions based on the CRPL Exponential Reference Atmosphere. However, the prediction method based on the reference atmosphere is recommended for general use because it leads to more accurate predictions at the lower elevation angles and is at least as good as the statistical method at all elevation angles.

Refractometers Developed. An improved airborne refractometer (Model 3) was developed for use in studies of tropospheric turbulence and radio refractive index. Model 3 has electrical performance much like that of a previous instrument (Model 2), but it has greater long-term stability. A transistor power supply and a different microwave configuration have reduced weight and power requirements. Overall, the instrument is approximately 5x8x12 inches and is intended for use in light aircraft.

A Birnbaum-type microwave refractometer (Model 4) was developed for Naval Research Laboratory, and was designed for use in a large aircraft. Model 4 was first used in measurements made in the South Atlantic to investigate refractive index inversions. Flights were made between Recife, Brazil, and Ascension Island. The instrument performed very well, and valuable data were obtained.

A new type refractometer (the Vetter Absolute Microwave Refractometer) is being developed. The instrument will require very simple circuits, and will feature improved stability and easier calibration.

Model Range Helps Predict Terrain Effects. Very good predictions of terrain obstacle effects can be made when an obstacle presents a single knife-edge type of obstruction, giving rise to the phenomenon known as obstacle gain. When more than one obstacle lies in the path, however, the prediction process becomes much more difficult.

To resolve some of the effects of multiple knife edges, a laboratory model propagation path was constructed for transmissions at 20 kMc. Measurements were made on this model range, and the characteristics of knife-edge propagation were shown extremely well. Clues were found to simplified methods for predicting the effects of multiple obstacles.

Bistatic Radar Cross Sections Measured. When flying over a propagation path, aircraft often reflect considerable amounts of energy to the receiving location, thus interfering with more direct paths. During the

operation of the Cheyenne Mountain-Haswell propagation paths in Colorado, this effect was measured while a B–17 aircraft moved through the path. These measurements indicated the amount of energy that the aircraft reflected to the receiving site. To analyze this phenomenon completely, it was necessary to know the incident energy and the reflecting properties of the aircraft. This type of reflection is expressed in terms of the bistatic radar cross section of the aircraft. Measurements were also made in a civilian aircraft flying over the same flight paths while the transmitter on Cheyenne Mountain was operating at 1046 Mc.

Attenuation of Building Materials Measured. In many practical communication problems, it is not possible to avoid transmitting radio waves through structures such as buildings, which have walls made of many materials. The question arises as to the effect of frequency, polarization, angle of incidence, and various other factors upon the attenuation of the electromagnetic energy passing through a wall.

A technique was developed for measuring attenuation in various building materials. A parallel wire grid was first used to assess the method and to determine diffraction around the edge of a sample. Laboratory measurements were made on wooden and masonry wall materials, and outdoor measurements were made on other building materials.

Television Field Strength Analyzed. Radiofrequency spectrum space is an urgent problem in television broadcasting. The Columbia Broadcasting System supplied the Bureau with a large amount of data on UHF television propagation. The Bureau is analyzing these data as part of its program of research on VHF and UHF tropospheric propagation characteristics. From these data, it has been determined that coverage would be improved if more than one station would broadcast the same program simultaneously in a given area.

A recording facility was established for continuously observing field-strength variations at a point just beyond the radio horizon. These data are expected to provide further information on transmission loss in the region of greatest variability.

Tropospheric Scatter Consulting. The Bureau assisted the Army in selecting sites and in planning the installation of some of its overseas communications networks that will use tropospheric scatter. Propagation paths between sites were analyzed, and performance estimates were made for these communications systems.

An extensive site selection expedition was made in Europe and North Africa for Air Force tropospheric scatter communications circuits. Data from this expedition were analyzed to determine the optimum frequencies, antenna size, and transmitter power. In predicting the performance of a given system on these paths, the Bureau developed a service probability concept which allows for the uncertainty in the prediction process.

A similar study was made for much shorter propagation paths used between Air Force communication relay centers and transmitter or receiver sites. Propagation characteristics were analyzed for each path.

VLF Noise Effects Measured. A better understanding is needed of radio system performance in the presence of noise. To fill this need, measurements were made of the amplitude distribution of carrier plus thermal noise. Good agreement was found between these measurements and predictions based on a mathematical analysis. The distribution of carrier-to-atmospheric noise, however, was found to differ appreciably from thermal noise. This difference might be anticipated from the distributions of atmospheric noise by itself. Instantaneous frequency distributions were found to depart appreciably from a normal distribution. Under conditions of carrier plus atmospheric noise, the shape of the instantaneous frequency distribution was found to be similar to that obtained with carrier plus thermal noise.

A study was made of radio systems operating in the presence of thermal and atmospheric noise. Power requirements were calculated for various systems operating in the presence of typical limiting noise. In addition, the system performance factor was found very useful for comparing the performance of various systems at various transmission rates and bandwidths.

Theoretical investigations indicated that, under certain conditions, multiple-frequency shift systems should perform better than binary frequency shift systems. A multiple-frequency system was designed and nearly completed. This system will permit experimental investigation of the system performance factor.

Frequency and Power Studied for VLF Standard Broadcast. A study was made of the power requirements and of an optimum frequency for a worldwide standard frequency broadcasting station. The expected transmission characteristics and atmospheric noise levels were calculated for the 8- to 100-kc band. When these factors are combined with carrier-to-noise requirements for a given precision of frequency comparison, a minimum radiated power is indicated (in the order of 10 to 100 kilowatts for frequencies in the vicinity of 20 kc) to provide worldwide coverage. To obtain a 1 in 10^9 precision for these transmitter powers over typical paths, observations are required for 15 to 30 minutes.

Radio Noise Data Gathered. Data were obtained from 15 stations in the worldwide network of radio noise recording stations. These data are hourly values of average power, average envelope voltage, and average logarithm of the envelope voltage, covering the frequency range from 13 kc to 20 Mc.

To supplement data from this worldwide network with information on the detailed character of the noise, equipment was designed and constructed to measure the amplitude-probability distribution of the noise envelope. Measurements made with this equipment were used to develop a method that allows a determination of the complete amplitude-probability distribution from the three statistical moments that are automatically recorded at the field stations.

Considerable progress was made on the development of an energy spectrum recorder that has been designed to sweep slowly across the spectrum

This masonry wall is typical of test structures constructed on the NBS r-f attenuation measurement range to study the transmission of radio waves through buildings and other structures (page 116).

and record continuously the average noise and signal power. This equipment will provide valuable information on noise levels as well as spectrum occupancy of signals. It will also provide propagation data over a large number of signal paths.

Methods were developed for isolating the three types of noise that influence recorded values. Manmade, atmospheric, and galactic noise reach the receiving antenna by ionospheric and groundwave propagation, and by direct radiation. Taking into account the prevailing propagation factors, the antenna pattern and source locations, these types of noise can now be analyzed separately.

The high-altitude nuclear blasts of August 1958 were observed to change the atmospheric noise levels recorded at Kekaha, Hawaii. Immediately following each blast, increased ionospheric absorption reduced the recorded values by as much as 30 decibels (db) over a wide range of frequencies. The levels remained much lower than normal for several days after each blast. Related effects at other stations are being investigated.

Teletype Errors Measured. Teletype errors were measured in a 638-mile tropospheric radio link. This set of measurements is one in a series to determine the short-term, median-carrier-frequency, signal-to-noise ratio required for radio links to give a certain performance in the presence of various types of short-term fading and for various kinds of systems. These systems included frequency modulation, single-side-band, dual diversity, and quadruple diversity. Quadruple diversity was used on the long path, and measurements were made of the correlation of the signals on the various paths.

The aim of the Bureau's program in radio communication and systems is to develop and disseminate technical information relating to radio systems that use propagation media and all frequencies of the radio spectrum. This information is directed toward guiding engineering practices, allocating and using radiofrequencies, and evaluating system capabilities. Standards and measurement methods are developed for radio systems to fulfill the needs of industry and Federal agencies involved in radio operation and regulation. Emphasis is placed on promoting more efficient development and use of radio systems and the radio spectrum.

New Division Established. To fulfill this mission, a new division was established to conduct comprehensive studies of radio techniques and equipment, propagation media, antennas, noise, modulation, detection and bandwidth requirements, frequency utilization, and operational requirements of radio services. The Radio Communication and Systems Division was formed in January 1959 from Bureau groups in which radio-systems studies had expanded appreciably in recent years.

In research at low and very low frequencies, experimental and analytical studies are made of electromagnetic wave propagation, atmospheric lightning discharges, and system techniques. In research at high and very high frequencies, experimental and analytical studies are made of techniques and wave propagation at frequencies from approximately 0.5 to 100 Mc. Research in modulation techniques throughout the radio spectrum is concerned with fading and multipath structure of the signals propagated by complex media. Statistical representations of time-varying signal characteristics, such as phase and amplitude variations, are providing bases for designing improved equipment to detect weak fluctuating signals in a background of radio noise. Experimental and analytical studies are made in radio navigation, positioning, and timing techniques. A substantial program of work is carried out in antenna research, and new design techniques and measurement methods are developed. Consulting and engineering assistance is provided in selecting, designing, and testing antennas for specific applications. In a new area of work, analytical studies will be made of overall radio system problems, especially of new radio system concepts, frequency utilization, and system performance. A network of ionospheric sounding stations is operated in Hawaii, Alaska, Puerto Rico, and Boulder, as well as other radio propagation field sites at Sterling, Va., and Long Branch (Kilbourne), Ill.

Arctic Communication Studied. At low and high frequencies, ionospheric radio propagation is unstable over radio paths that cross the polar cap or that pass through regions of maximum auroral activity. These frequencies are needed for long-range communication, especially between ground stations and aircraft or ships. Communication may be impaired, however, for days at a time by intense absorption (caused by abnormal ionization in the *D*-region) or by signal mutilation (caused by multipath propagation, rapid fading, and spectral dispersion). Available statistical

data are inadequate for needed estimates of performance reliability over long periods.

Studies were made of losses and fluctuation in high- and low-frequency transmission over long paths that are subject to polar and auroral disturbances.

Transarctic Terminal Sought. For the Navy Bureau of Ships, a project was started to find an optimum geographical site for a transarctic communication terminal in the United States. Over a pattern of receiving stations, comparisons will be made of transmission loss statistics, fading characteristics, and elevation angles of signals received from transmissions in northern seas.

Ionospheric Signals Studied. For Wright Air Development Center, studies are being made of ionospheric transmission of pulse and continuous wave signals at low and high frequencies. These studies are needed in planning for long-range air-to-ground communications. Transmission loss characteristics are being studied, as well as fading and dispersion of these signals, because these factors must be appraised in developing effective modulation techniques.

Meteor Burst Communication System. An experimental communication system was operated by using meteor trails to reflect radio signals from a transmitter to a receiver 800 miles away. With this system, messages were sent at speeds up to 4,800 words per minute—80 times the present speed of transmission by teletype. The system was developed under the sponsorship of the Air Force Cambridge Research Center.

A study was made of the effect of speedup ratio on the system and it appears that the system operates most effectively at 2,400 words per minute. At this speed, and with a suitable operating threshold setting, the system attained a daily average of 40 words per minute and had a character error rate of 0.35 percent.

Modulation Techniques Investigated. In studies of modulation techniques for ionospheric scatter transmission, further radiotelephone and binary modulation problems were investigated. Phase stability of the ionspheric scatter medium was studied in relation to the limitations imposed on phase-keying techniques for binary transmission. Methods were studied for circumventing errors in frequency shift caused by Doppler-shifted meteoric echoes. A simple technique was tested for using a shift index as small as required by the signaling speed. This technique was found to reduce the Doppler errors as effectively as the conventional technique of using a large frequency shift. Thus a way is open for reducing bandwidth requirements of frequency shift systems. A study was also made of the maximum usable bit rate under normal limitations of the propagation medium. Frequency and amplitude (single side band) modulation techniques were studied for radiotelephone transmission using ionospheric scatter for single-link and multihop relay transmissions, as well as under conditions of multipath propagation of backscatter signals propagated in the F_2-layer.

In developing basic techniques for modulation studies at all frequencies, magnetic tape recordings were made of modulated radiofrequency signals received. Repetition of the complex fading signal is thereby made available for analysis and comparative adjustments of detection and diversity arrangements. Techniques were developed and used for analyzing fade duration at high and very high frequencies.

Special Antennas Developed. A major program was completed in measuring the characteristics of corner reflector antennas. This program led to comprehensive design information for gain and beamwidth as a function of dimensions and angle of the corner reflector. A special corner reflector antenna was developed for ionospheric scatter and meteor burst communication applications.

An antenna with 20-db gain (and having 10 collinear-driven elements) was designed to achieve 40-db suppression of radiation outside the main lobe, thus reducing interference and backscatter multipath effects at very high frequencies.

Performance was measured for a number of typical commercial very high frequency antennas, to aid in evaluating the importance of television receiving antennas in allocating television frequencies.

Tests were made on full-scale antenna systems for the Air Force, and a theoretical study was made of interlaced rhombic antenna arrays. Further development and instrumentation is planned for accurate measurements of antenna performance, and arrival angles will be measured by a directive antenna having a very high resolving power.

Polar Icecap Conductivity. In VLF propagation research, analyses were made of atmospheric propagation associated with lightning discharges. Atmospheric noise source characteristics were studied based on analyses of

NBS mobile laboratories make it possible to study radio conditions in many parts of the world. At left is a unit at Boulder, Colorado, and at right is a station in North Africa (page 116).

groundwaves from discharges at distances from 150 to 700 km. Attenuation factors were computed for ranges of 1,000 to 8,000 km by comparing the amplitude spectra of the same atmospheric disturbance that was recorded at different distances. Based on airborne field strength measurements over Greenland, information was obtained concerning tilt of signals, and the conductivity and dielectric constant of the icecap.

Pulse Propagation Problem Solved. In theoretical work, modern numerical analysis was applied to the groundwave and skywave complex spectrum. The problem of pulse propagation for both the groundwave and skywave was solved in a very general and rigorous manner by applying the theory of Gaussian quadrature in evaluating the time-harmonic Fourier integral-transform.

Radio Navigation Studies Made. Studies were made of low and very low frequency methods for radio navigation, timing, and positioning. These studies included analysis of propagation aspects of the Loran C navigation technique. Studies were also made of very low frequency azimuth detection and timing; complex spectrum recording and measurement; and data storage, selection and recording.

Space Communication Studies Begin. In the rapidly developing field of space communications, investigations began into problems of communication between space vehicles, and space vehicles and the earth. Solutions are needed for these radio propagation and system problems to enable the efficient system design and allocation of frequencies for space applications.

2.15. Radio Standards

The Bureau's program in radio standards consists of basic research and development on national standards of fundamental electrical quantities, measurement techniques, and properties of materials. A large calibration service is provided from direct-current through microwave frequencies, and radiobroadcasts are made of the national primary standards of frequency and time intervals.

During the last few years, demands have increased for radio standards of electrical quantities and for the properties of many radio materials. Extensive calibration programs are being established in military agencies, industries, and in private standards organizations. These programs depend upon the Bureau's best reference standards. Demands for the Bureau's radio standards services were emphasized by the results of questionnaires on standardization needs, submitted by various professional groups to their affiliated industries, such as the one submitted by the Aerospace Industries Association.

Attenuation Calibration Service. In many electronic measuring instruments, radiofrequency attenuators are widely used, and there is an urgent demand for their standardization. A calibration service was offered for microwave attenuation from 12.4 to 18.0 kMc, and refinements are being made so that needed accuracies can be achieved in systems for measuring

attenuation above and below this frequency range. Six new waveguide-below-cutoff attenuators were built, tested, and used in measuring microwave attenuation.

A precision phase shifter was built for use in making measurements of high-frequency attenuation. In performance tests, changes in impedance were found to be less than 0.1 percent, as the phase shifter was varied. A new method was devised for measuring the change in the output signal level as the phase is varied. With this method, sensitivities were obtained which were estimated to be better than 0.0001 decibel.

Field-Strength Standards Being Developed. Standards of field strength are needed because of the wide use being made of field-strength meters in establishing radar systems and communication paths. Versions of these meters are also used to determine whether radiation levels are hazardous to personnel.

Progress was made toward establishing national standards of microwave field strength. A microwave absorbing enclosure and its construction material are being evaluated. In this work it was found necessary to increase the stability and resolution of the insertion loss measuring system, and several improvements were made. A technique was also devised for investigating an optimum radiofrequency and final detector system.

Frequency Standards Improved. Scientific and government research laboratories require frequency calibrations to accuracies approaching those available from the national primary frequency standards. Recent developments in satellites and missiles have emphasized the need for more precise time measurements.

A cesium-beam apparatus was rebuilt and a precision of 2 parts in 10^{10} was attained. An improved atomic beam machine, nearing completion, is expected to provide even higher precision. This machine will also have greater reliability, convenience, and ease of operation. Plans were made for an entirely new frequency multiplier chain that is needed for the atomic beam machine. Comparisons were made between a chain stabilized with a maser, and a quartz oscillator cooled with liquid helium. They were found to be equally stable for periods of 4 hours (see also p. 43).

Precision was improved from 1 part in 10^9 to a few parts in 10^{10} for measuring the interval between time signals broadcast by WWV and WWVH.

In cooperation with the Army Signal Corps, the Bureau made a unique experiment that increased confidence in the method used for precise measurements of the frequency transmitted by WWV. An atomic frequency standard was transported from place to place and intercompared with the frequency of several widely separated atomic standards, including those at WWV and Boulder. Measurements were made by the direct comparison method and by means of the long-time interval method via high-frequency time signals received at Boulder. These measurements agree to 1 part in 10^{10} or better.

Quartz Oscillators Investigated. Quartz crystal oscillators were investigated at 4° K, and a second-to-second frequency stability of 2 parts in 10^{11} was obtained. This stability is believed to be 10 times better than for

any other oscillator. It was shown that aging of these crystals changes their stability by less than 2 parts in 10^{11} per day over a period of 1 year. Much of this work was done under the sponsorship of the Army Signal Research and Development Laboratories.

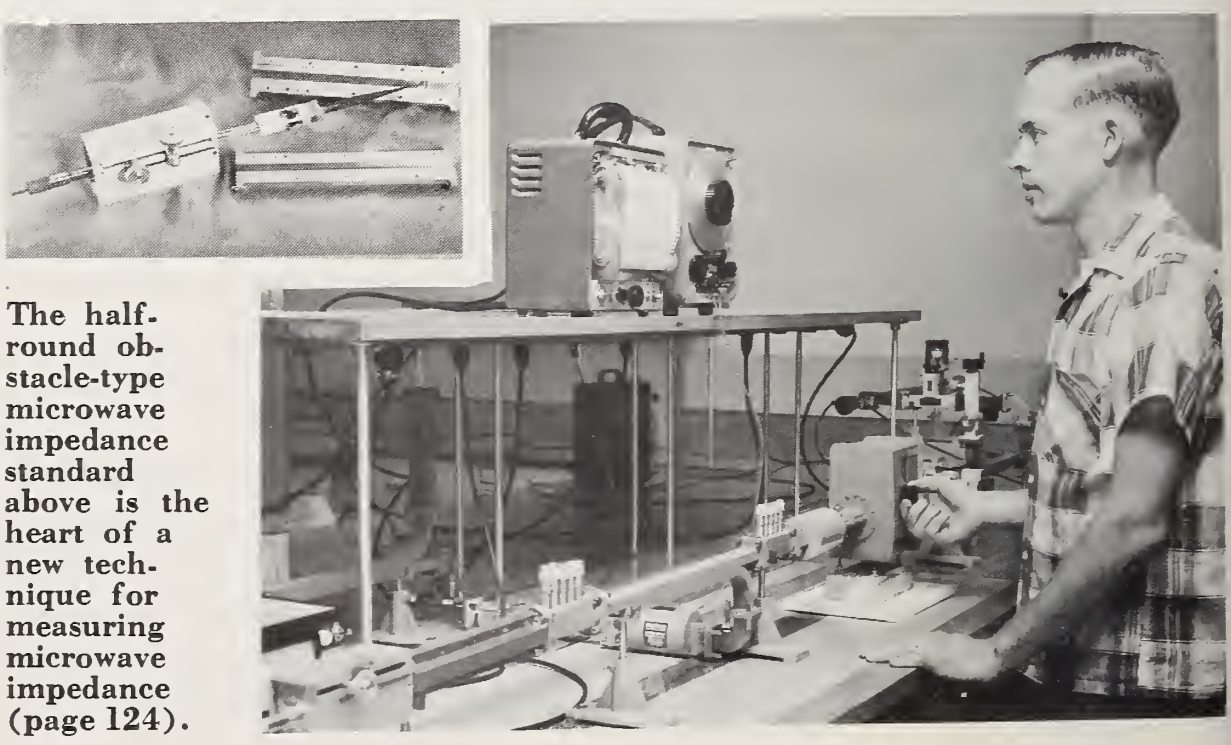
In an investigation of properties of crystalline quartz as related to their use in high-frequency resonators, various impurities were removed or introduced in quartz. The electrical conductivity of quartz was measured along two axes, and a current anomaly was discovered which apparently relates the removal of crystal dislocations to the electrical conductivity.

Impedance Standards Analyzed. In making accurate measurements of attenuation, power, voltage, field strength, and other quantities, it is essential to know the impedance of a transmission system. The large demand for the calibration of impedance components, such as resistors, capacitors, and inductors, has made impedance standards vitally important.

To give full status as independent absolute standards to the new microwave impedance standards (half-round obstacles in rectangular waveguide), a theoretical analysis is being made of finite conductivity effects and geometrical imperfections. For treating this and similar problems, a new perturbation theory was originated. This theory is based on a general variational principle for elements of immittance matrices of waveguide junctions, which is believed to be new, although closely related to known results.

In preparation for its use as a national reference standard at high frequencies, a 2 picofarad (2×10^{-12} farad) derived incremental capacitor is being intercompared with other standards.

Impedance Calibration Techniques Developed. A suitable technique was developed for calibrating microwave impedance standards by use of WR 90 rectangular waveguide. The technique was applied to coaxial systems for measurements from 1 to 18 kMc.



The half-round obstacle-type microwave impedance standard above is the heart of a new technique for measuring microwave impedance (page 124).

A technique was also devised for comparing newly designed precision short-circuit types of microwave impedance standards and for measuring attenuation in short lengths of waveguide. This technique was shown to be suitable for evaluating primary standards of impedance.

Receivers Analyzed for Spurious Response. When several transmitters and receivers are operated simultaneously in proximity, their output should be limited to their principal emissions at their assigned carrier frequencies. In developing equipment to meet this requirement, spurious power outputs must be measured reliably. Under the sponsorship of the Navy Bureau of Ships, the Bureau is developing standard techniques for this purpose.

Four types of Navy receivers were analyzed for spurious responses as the input signal level was varied. These receivers, covering the range from 14 kc to 1 kMc, will be used to measure spurious outputs of transmitters. Attenuation characteristics were determined for 23 rejection filters (14 kc to 1 kMc).

Noise-Measuring Equipment Designed. For some electronic instruments performance is limited by noise; and, in radio astronomy and plasma physics, data are random (noisy) in character. Standards of noise power, therefore, have become very important.

A microwave radiometer was developed for comparing the outputs of two noise sources, and the final analysis of this equipment is being made. An analysis was made of the electrical and thermometric precision required of a high-frequency noise-generating system. Design and construction were started for a new noise source and generator. Construction began for a special monitor that is designed to have characteristics essential in noise measurements. Two new input systems were devised to meet the requirements of gain stability in measuring noise power.

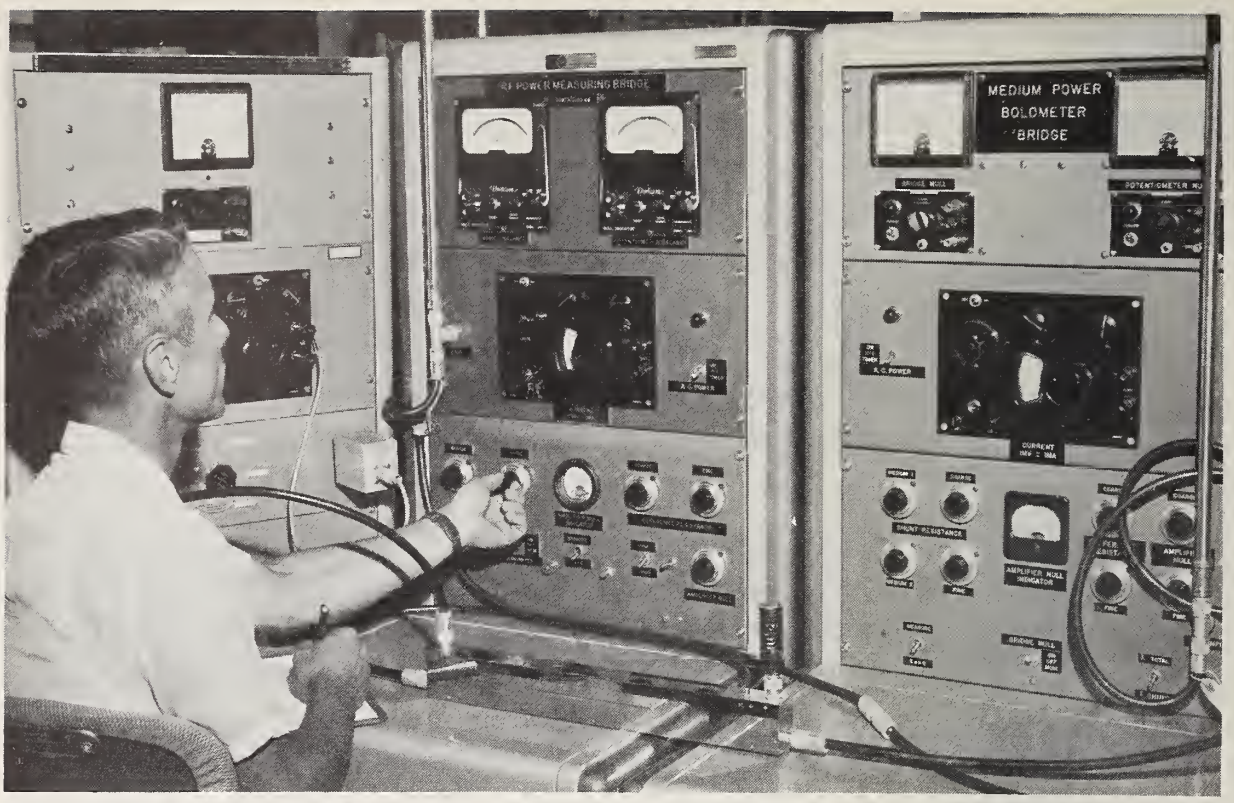
Power Standards Built. Standards of power are needed for measuring the range of radar and radio relay equipment as well as for measuring the output of other power sources used in many fields of science.

The Bureau's *X*-band microwave microcalorimeter was improved to an accuracy of ± 0.2 percent by refining its bolometer mounts. A second pair of bolometer mounts was built, calibrated, and sent to England for intercomparison as recommended by Commission I of the International Scientific Radio Union.

For use as reference standards at high frequencies, directional coupler radiofrequency power meters were designed and built. After careful calibration by independent methods, this series of standards will be compared with the standards of other countries.

To permit measurement of power at high frequencies, a 2-kw calorimeter and 1-kw, 100-Mc power amplifier were built.

Voltage Calibration Services. A large number of instruments such as radiofrequency voltmeters, voltage sources, and modulation meters are used throughout the electronic industry. Calibrations and standards for these instruments are, therefore, of major importance.



Calibrating a directional coupler r-f power meter which was constructed to serve as a reference standard for international comparisons of r-f power standards (page 125).

With the addition of new equipment, voltage calibration services can now be furnished from 30 kc to 400 Mc by the Electronic Calibration Center. Recalibration of attenuator-thermoelement (AT) voltmeter reference standards showed that most remained within 1 percent of their original calibration for more than a year.

A new microvoltage console was partially completed. It will be used to calibrate radiofrequency millivoltmeters and signal generators from 1 microvolt to 0.1 volt at the Electronic Calibration Center.

Dielectric Properties Determined. Because dielectric materials are used in many radio and microwave applications, accurate measurements of their properties are needed for efficient electronic designs.

A prototype copper extension cell was tested for use in a slotted-line high-temperature dielectrometer. A silver cell is being finished and will operate to 800° C. By programing some calculations for an automatic computer, the speed and accuracy of microwave dielectric calibrations were increased.

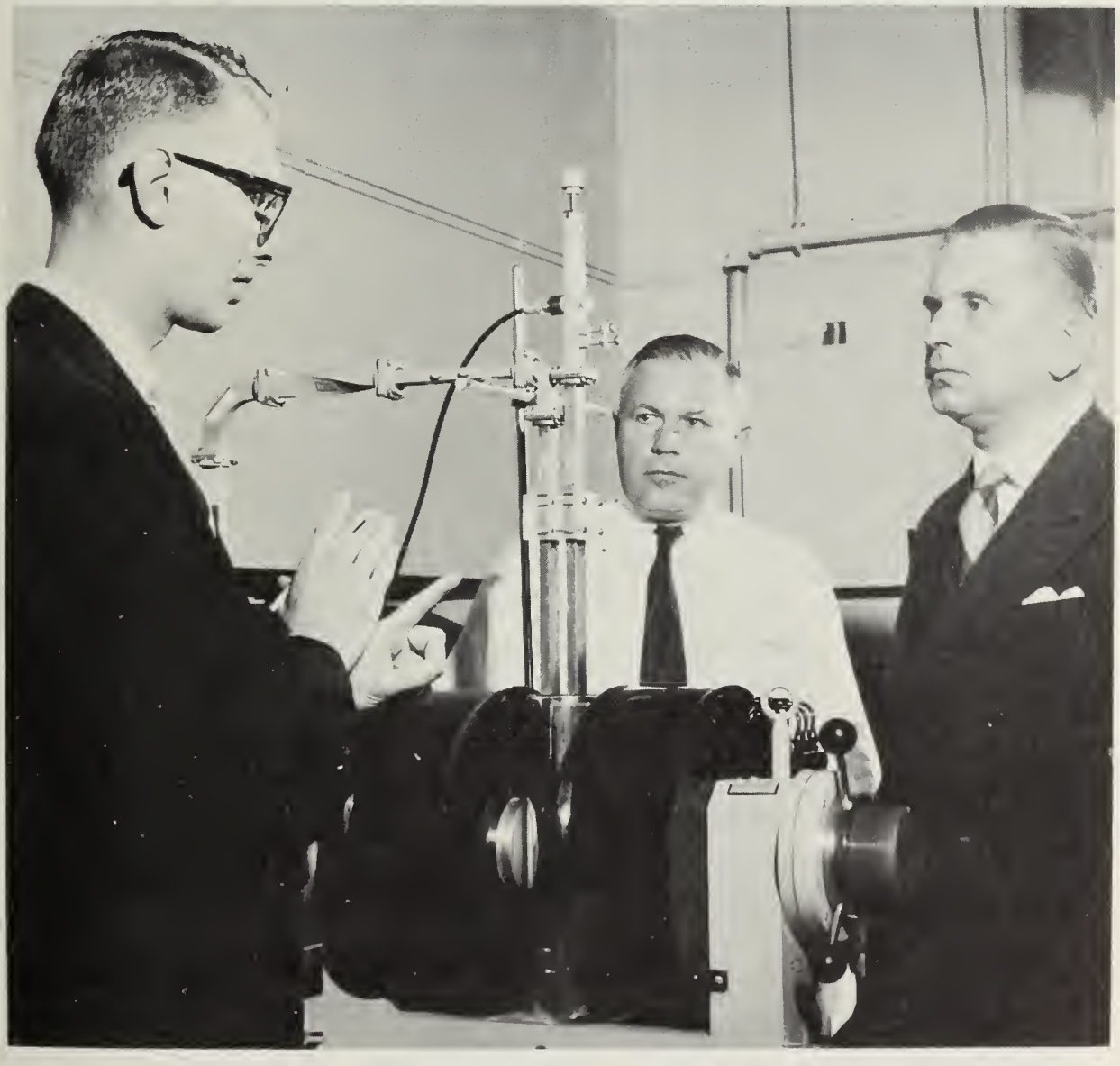
Dielectric properties were determined at radiofrequencies for various materials, including samples of porcelains, boron nitride, crude oil and oil shale, and both fresh water and sea water.

Magnetic Properties of Materials Measured. Magnetic materials are used extensively in commercial and military electronic systems. To support the vast effort being directed toward studying and applying these materials, new and better measuring techniques, equipment, and standards are needed, as well as fundamental studies of the properties of these materials. Work during the last year was concerned with all of these areas.

A quasi-static hysteresis loop plotter was completed, as was a series of improved permeameters designed to shorten the time required to measure magnetic spectra and to improve the precision of Q measurements. Improvements were also made to four other instruments used to study the spectra of ferrites or to make measurements of permeability. A calorimeter was completed for measuring high-power radiofrequency loss in ferrites as a function of a-c field strength at 300 kc.

The properties of ferrite materials were investigated under the sponsorship of the Navy Bureau of Ships. Complex permeability data were obtained for 48 materials (144 toroids) at 100 and 300 Mc, and their total loss was measured as a function of magnetic field strength at 0.3 Mc (48 toroids). Reversibility permeability was measured for eight additional materials (24 toroids).

In related projects, microwave tensor permeability and dielectric constants were measured for selected ferrites. Instrumentation was put into operation for making these measurements at additional frequencies. When correlated



Bureau scientists explain a low-temperature microwave experiment to an Australian microwave physicist. The equipment was used in studying the conductivity properties of germanium (page 126).

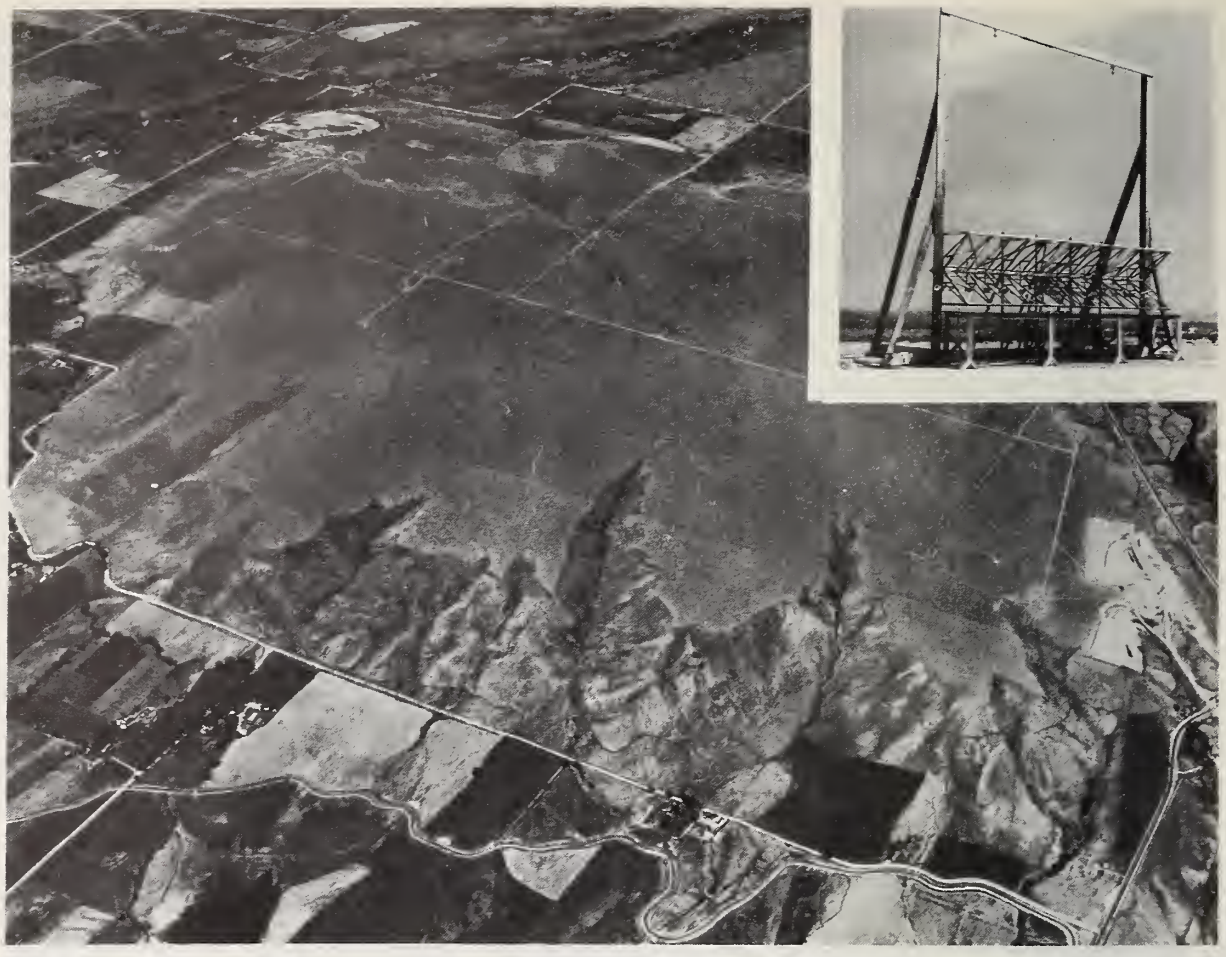


Table Mesa, near Boulder, Colorado, is an excellent natural site for a wide variety of radio research programs. For example, it serves as an antenna testing range, and is the receiving end for radio paths having transmitters at Long Branch, Illinois, Haswell, Colorado, and Barrow, Alaska. Inset shows the experimental setup on Table Mesa for measuring the performance characteristics of corner reflector antennas (page 121).

with other physical properties, these data will permit more effective evaluation of the ferrites for specific electromagnetic requirements.

Ferrites Laboratory. With support from the Navy Bureau of Ships, the Bureau is establishing a ferrites laboratory to coordinate and evaluate the work on radio and microwave magnetism in this country. The laboratory will explore basic phenomena and develop standard methods and techniques for evaluating rapid advances in magnetic materials and devices. A facility will also be maintained for reference testing.

Microwave Interferometers Developed. Preparations were made for a precise experimental determination of the velocity of light. A wavelength of 6.28 mm will be used in a microwave Michelson interferometer operating in the Fresnel region of diffraction.

A pilot model of a microwave Fabry-Perot interferometer was operated at a wavelength of 6 mm. The fringes obtained were the sharpest ever reported for this type interferometer, and the work shows the superiority of the microwave form of this interferometer over its optical counterpart.

Time and Frequency Standards. To make the national standards of frequency and time intervals readily available, broadcasts were made continuously from WWV (Beltsville, Md.); WWVH (Maui, Hawaii); and from KK2XEI (an experimental 60-kc station at Boulder, Colo.). These broad-

casts are widely used by industry, government agencies, and schools, in research activities, defense systems, communications, navigation, broadcasting, and manufacturing.

The frequency transmitted by WWV was measured daily at the Boulder Laboratories in terms of atomic standards by means of the time-interval method. Measurements made at Beltsville were compared with a second atomic standard. The results showed that, when a suitable averaging period is used, the time-interval method will give values within a few parts in 10^{10} of the actual transmitted frequency. Numerous improvements were made in the WWV electronic equipment to increase the stability and reliability of the transmitted signals.

The experimental 60-kc broadcast continued to furnish many users with a service that is much more accurate than the one supplied by WWV. The low radiated power of this broadcast, however, has limited its use. Because many research, military, and industrial organizations need the higher accuracies of the 60-kc broadcast, considerable planning work was done toward a high-power standard broadcast station near Boulder. Measurements and theoretical studies have shown that at very low frequency, the received frequency may be 1,000 times more precise than at high frequency. As a direct result of some of these studies, a method was under development for modulating time-signal, very-low-frequency carriers so that the station will permit frequency and time-interval calibrations to a precision and accuracy far greater than at high frequency.

Mobile laboratory containing recording apparatus and roof turntable used to track aircraft in antenna evaluations for the U.S. Air Force (page 121).

Electronic Calibration Center. This Center provides extensive calibration services for industry and Defense Department agencies that are engaged in very rapidly expanding their own standards and calibration programs.

Fiscal year 1959 was the first full year of operation of the Center. Although instrumentation for the Center was far from complete, it was possible to meet a large part of the increasing demand for calibration services, in those areas in which national standards had been set up. As was expected, the low-frequency calibration service expanded rapidly since measurement techniques and calibration equipment were made available. Coaxial and waveguide attenuators, and couplers at microwave frequencies were a large part of the total calibration work at the higher frequencies. Many needed calibration services were not offered because of the lack of suitable measurement techniques and instrumentation.

Instrumentation initially planned for the low-frequency region provides for calibrating electrical instruments, resistors and resistance apparatus, inductors and capacitors, standard cells, current and voltage transformers, and miscellaneous, including ratio devices. Calibration facilities are being established for instruments measuring high-frequency voltage, power, impedance, attenuation, and field-strength. In the microwave region, instrumentation is being prepared for precision calibrations of instruments measuring power, impedance, attenuation, frequency, and noise.

2.16. Weights and Measures

One of the statutory responsibilities of the National Bureau of Standards is "cooperation with the States in securing uniformity in weights and measures laws and methods of inspection." The responsibility of regulatory control over commercial weighing and measuring devices and commercial transactions involving quantity has been left by the Congress to the individual states. The Bureau contributes by offering consultative and advisory services to the States and calibration and physical adjustment of State reference weights and measures standards.

This program is implemented through the Bureau's Office of Weights and Measures. The range of services is quite broad, including: (1) Development of model weights and measures statutes, rules, and regulations; (2) properly designed and accurate physical standards of length, mass, and capacity; (3) effective procedures for testing commercial weighing and measuring devices; (4) specially designed testing equipment; (5) plans for systematic and effective quantity checking of prepackaged merchandise; (6) administrative procedures; (7) specifications and tolerances for commercial devices; (8) training schools for weights and measures officers; (9) visual aids; and (10) publications.

The Office of Weights and Measures was relocated during the year to provide space for a training laboratory and for the weights and measures archival and reference library. A comprehensive collection of published material on weights and measures in the United States is being assembled in

the special library. Its facilities will be available not only to the Bureau's staff but to all students and researchers in this field.

The training laboratory will facilitate the development of testing procedures and will enable the Bureau to offer short, comprehensive courses to supervisory and training personnel of State and large local jurisdictions in the many facets of weights and measures supervision. The demand for such training continues to grow. Requests by the States for formal technical training schools are such as to severely tax the facilities and staff of the Office of Weights and Measures. The results of this program are very encouraging, as evidenced by more uniform, more effective, and more efficient weights and measures supervision at the State and local levels.

The Bureau was called upon by the governments of several States for assistance in the preparation of weights and measures legislation. Complete statutes, based on the model weights and measures law, were enacted in Washington, New Mexico, and Missouri, and major amendments to existing laws were adopted in other States.

A significant addition to the technical literature was published during the year, "Checking Prepackaged Commodities," a handbook for weights and measures officials. The first such publication in the field, it presents a guide for checking packaged commodities as to the accuracy of their quantity declarations, with a procedure based on sound statistical sampling principles.

At the request of the National Conference on Weights and Measures, effort is being devoted to the development of new physical standards of weights and measures for the States—standards that will be more accurate, more constant, and more durable. Basic studies in materials and design were completed during the year. In 1836 and in 1866, the Congress provided the States with reference standards that became the basis for nationwide uniformity. Since then, through obsolescence and some individual purchases, nonuniformity in the physical characteristics of the standards has developed among the States. The Bureau's current efforts will provide a sound basis for repeating the 19th-century actions. This would bring about complete uniformity among the States in the area of weights and measures reference standards.

In an impressive ceremony held at the Bureau during the year, a set of weights and measures comprising standards of length, mass, and capacity was presented to the new State of Alaska by Secretary of Commerce Lewis L. Strauss. These standards are providing a firm basis for an accurate, uniform measurement system in the new State, so vital to the growth of commerce and industry.

Traditionally, the National Conference on Weights and Measures has been one of the principal means of promoting uniformity and raising performance standards in weights and measures administration in the United States. Sponsored by the Bureau, the 44th Annual Conference was held in Washington D.C., during the year. Thirty-nine States, Puerto Rico, and the District of Columbia were officially represented at this 5-day meeting by 197 delegates out of a total registered attendance of 389.

2.17. Basic Instrumentation

The fundamentals of measurement and control were emphasized in the Bureau's research and development in basic instrumentation. An instrument reference service was operated and enlarged, research and development continued on information retrieval systems, and instrumentation methods were surveyed. Support for this program was contributed by the Office of Naval Research, the Department of Defense, and the Atomic Energy Commission.

Instrument Reference Service Enlarged. Industrial and government scientists must know what has been done in developing instruments to establish effective designs without duplication of effort. The Bureau's office of basic instrumentation provides reference and consultation services for all scientists who work in research and development of scientific instruments.

The Bureau enlarged its card index of instrumentation literature by selecting, analyzing, coding, and recording additional information in a special punched-card system. A large number of inquiries were answered by use of references already stored in this index system.

Work continued on developing methods of replicating the punched cards used in the Bureau's instrument reference files. A design was completed for an electromechanical device to increase the speed and efficiency of searching the instrument index.

Instrumentation Methods Surveyed. A survey was made of recording surfaces and marking methods used in industrial processes or for laboratory experiments. This survey was published as NBS Circular 601, and work is continuing on the second part of the survey, dealing with recorder principles and mechanisms. A survey was started on electrical methods of varying capacitance. A survey was also made of the Bureau's need for automatic data taking in its research work, and a number of useful applications were found for these methods.

3. Appendixes

3.1. Organization of The National Bureau of Standards*

Director—Allen V. Astin

Deputy Director—Robert D. Huntoon

Assistants to the Director
Henry Birnbaum and C. N. Coates

Consultants to the Director
F. G. Brickwedde, L. F. Curtiss,
A. G. McNish, and C. H. Page

Associate Director for Physics
Robert D. Huntoon

Associate Director for Engineering
Archibald T. McPherson

Associate Director for Chemistry
Edward Wichers

Consultants to the Associate Director
W. Souder and M. B. Wallenstein

Associate Director for Planning
Irl C. Schoonover

NBS Reactor Program
C. O. Muehlhause

Associate Director for Administration
R. S. Walleigh

Associate Director for the Boulder Laboratories
Frederick W. Brown

Director Emeritus—Lyman J. Briggs

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Electron Devices, C. P. Marsden,
Electrical Instruments, F. M. Defandorf
Magnetic Measurements, I. L. Cooter
Dielectrics, J. D. Hoffman
Engineering Electronics, G. Shapiro
Electronic Instrumentation, G. F. Montgomery
Electrochemistry, W. J. Hamer

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D. B. Judd, *Assistant Chief*

Photometry and Colorimetry, L. E. Barbrow
Optical Instruments, F. E. Washer
Photographic Technology, C. S. McCamy
Length, B. L. Page, *Acting*
Engineering Metrology, I. H. Fullmer

* As of Sept. 1, 1959.

HEAT, C. M. Herzfeld, *Chief*
K. E. Shuler, *Consultant*

Temperature Physics, J. F. Swindells
Thermodynamics, C. W. Beckett
Cryogenic Physics, R. P. Hudson
Rheology, R. S. Marvin
Molecular Kinetics, F. L. Howard
Free Radicals Research, A. M. Bass

ATOMIC AND RADIATION PHYSICS, L. S. Taylor, *Chief*

Atomic Physics Laboratory

Spectroscopy, K. G. Kessler
Radiometry, E. K. Plyler
Mass Spectrometry, F. L. Mohler
Solid State Physics, H. P. R. Frederikse
Electron Physics, L. L. Marton
Atomic Physics, L. M. Branscomb

Radiation Physics Laboratory, H. O. Wyckoff, *Chief*

Neutron Physics, R. S. Caswell
Radiation Theory, U. Fano
Radioactivity, W. B. Mann
X-ray, H. O. Wyckoff
High Energy Radiation, H. W. Koch
Nucleonic Instrumentation, L. Costrell
Radiological Equipment, S. W. Smith

CHEMISTRY, E. Wichers, *Acting Chief*
R. G. Bates, *Acting Assistant Chief*

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Surface Chemistry, W. W. Walton
Organic Chemistry, H. S. Isbell
Analytical Chemistry, H. A. Bright
Inorganic Chemistry, R. Gilchrist
Electrodeposition, A. Brenner
Molecular Structure and Properties of Gases, F. Buckley
Physical Chemistry, R. G. Bates
Thermochemistry, E. J. Prosen
Spectrochemistry, B. F. Scribner
Pure Substances, C. P. Saylor

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W. G. Brombacher, *Consultant*
J. M. Frankland, *Consultant*

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Mechanical Instruments, E. C. Lloyd
Fluid Mechanics, G. B. Schubauer
Engineering Mechanics, L. K. Irwin
Mass and Scale, H. S. Peiser
Capacity, Density, and Fluid Meters, C. T. Collett, *Acting*
Combustion Controls, F. R. Caldwell

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Textiles, H. F. Schiefer
Paper, R. B. Hobbs
Leather, J. R. Kanagy
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Polymer Structure, N. P. Bekkedahl
Plastics, F. W. Reinhart
Dental Research, W. T. Sweeney

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T. G. Digges, *Assistant Chief*

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Chemical Metallurgy, L. L. Wyman
Mechanical Metallurgy, J. A. Bennett
Corrosion, G. A. Ellinger
Metal Physics, L. M. Kushner

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C. H. Hahner, *Assistant Chief*
L. H. Adams, *Consultant*
R. F. Geller, *Consultant*

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Glass, C. H. Hahner
Refractories, C. H. Hahner, *Acting*
Enameled Metals, W. N. Harrison
Constitution and Microstructure, H. F. McMurdie

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H. R. Snoke, *Assistant Chief*
W. F. Roeser, *Consultant*

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Fire Protection, A. F. Robertson
Air Conditioning, Heating, and Refrigeration, P. R. Achenbach
Floor, Roof, and Wall Coverings, H. R. Snoke
Codes and Safety Standards, J. A. Dickinson
Heat Transfer, H. E. Robinson
Concreting Materials, R. L. Blaine

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F. L. Alt, *Assistant Chief*

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Computation, E. W. Cannon, *Acting*
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Mathematical Physics, R. F. Dressler

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H. K. Skramstad, *Assistant Chief for Systems*

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Digital Circuitry, S. Greenwald
Digital Systems, A. L. Leiner
Analog Systems, H. K. Skramstad
Applications Engineering, S. N. Alexander, *Acting*

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M. W. Jensen, *Assistant Chief*
R. W. Smith, *Consultant*

OFFICE OF BASIC INSTRUMENTATION, W. A. Wildhack, *Chief*
J. Stern, *Assistant Chief*

OFFICE OF TECHNICAL INFORMATION, W. R. Tilley, *Chief*
W. K. Gautier, *Assistant Chief*

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Administrative Services, H. P. Dalzell
Shops, F. P. Brown
Supply, G. B. Kefover
Management Planning, I. Asay
Budget, N. L. Christeller
Internal Audit, J. P. Menzer
Plant, H. Graham

BOULDER LABORATORIES, F. W. Brown, *Director*

Boulder, Colorado

Gaseous Physics Group, J. M. Richardson
Consultant in Statistics, E. L. Crow
Consultant in Astrophysics, R. N. Thomas
Consultant in Radio Wave Propagation, J. R. Wait
Consultant in Mathematics, J. Sopka

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B. W. Birmingham, *Assistant Chief*

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Cryogenic Processes, B. W. Birmingham
Properties of Materials, R. J. Corruccini
Gas Liquefaction, V. J. Johnson

RADIO PROPAGATION PHYSICS,* R. J. Slutz, *Chief*
D. M. Gates, *Assistant Chief*
A. H. Shapley, *Assistant Chief*
T. N. Gautier, *Consultant*
D. K. Bailey, *Consultant*

Upper Atmosphere Research, R. M. Gallet
Ionosphere Research, E. K. Smith, Jr.
Regular Prediction Services, W. B. Chadwick
Sun-Earth Relationships, R. W. Knecht
VHF Research, K. L. Bowles
Radio Warning Services, Miss J. V. Lincoln
Airglow and Aurora, F. E. Roach
Radio Astronomy and Arctic Propagation, C. G. Little

RADIO PROPAGATION ENGINEERING,* K. A. Norton, *Chief*
J. W. Herbstreit, *Assistant Chief*
E. F. Florman, *Consultant*

Data Reduction Instrumentation, W. E. Johnson
Radio Noise, W. Q. Crichlow
Tropospheric Measurements, C. F. Peterson
Tropospheric Analysis, P. L. Rice
Propagation-Terrain Effects, R. S. Kirby
Radio-Meteorology, B. R. Bean
Lower Atmosphere Physics, M. C. Thompson, Jr.

*These divisions comprise the Central Radio Propagation Laboratory.

RADIO COMMUNICATION AND SYSTEMS,* R. C. KIRBY, *Chief*
D. W. PATTERSON, *Assistant Chief*
A. D. WATT, *Assistant Chief*
G. W. HAYDON, *Consultant*

Low Frequency and Very Low Frequency Research, A. G. JEAN
High Frequency and Very High Frequency Research, R. SILBERSTEIN
Modulation Systems, J. W. KOCH
Antenna Research, H. V. COTTONY
Navigation Systems, G. HEFLEY
Systems Analysis, W. C. COOMBS
Field Operations, H. G. SELLERY

RADIO STANDARDS, W. D. GEORGE, *Acting Chief*

W. D. GEORGE, *Assistant Chief for Radio Frequencies*
D. M. KERNS, *Assistant Chief for Microwave Frequencies*
E. C. WOLZIEN, *Assistant Chief for Technical Planning and Coordination*
W. W. BROWN, *Consultant*
P. F. WACKER, *Consultant*

High-Frequency Electrical Standards, M. C. SELBY
Radio Broadcast Service, A. H. MORGAN
Radio and Microwave Materials, J. L. DALKE
Electronic Calibration Center, H. W. LANCE
Microwave Circuit Standards, R. W. BEATTY

ADMINISTRATIVE DIVISION, S. W. J. WELCH

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

Lamp Inspector, Brookline, Mass.
Visual Landing Aids Field Lab., Arcata, Calif.
Master Railway Track Scale Depot, Clearing, Ill.

Materials Testing Laboratories:

Allentown, Pa.
Denver, Colo.
San Francisco, Calif.
Seattle, Wash.

Radio Transmitting Station WWV, Beltsville, Md.
Maui Ionosphere and WWVH Station, Maui, Hawaii

Central Radio Propagation Laboratory Field Stations:

Anchorage, Alaska
Barrow, Alaska
Marie Byrd Base, Antarctica
Pole Station, Antarctica
Cheyenne Mountain, Colo.
Fritz Peak, Colo.
Gunbarrel Hill, Colo.
Haswell, Colo.
Lafayette, Colo.
Sunset, Colo.
Table Mesa, Colo.
Kekaha, Hawaii
Long Branch, Ill.
San Juan, P.R.
Fort Belvoir, Va.
Front Royal, Va.
Sterling, Va.
Bill, Wyo.

3.2. Fiscal Data on NBS Program

Program and Source of Financing	Obligations Incurred (in thousands of dollars)		
Supported by NBS Appropriations:			
Operating Programs:			
Expenses		$12,379	
Construction and Facilities Programs:			
Plant and Equipment	$569		
Construction of Facilities	2,140		
		2,709	
Total NBS Appropriations			$15,088
Supported by Other Funds:			
Research and Development Programs:			
Other Federal Agencies	14,720		
Nongovernmental Sources	143		
		14,863	
Calibrations, Testing, and Standard Samples		3,732	
Reimbursable Administrative Services		1,156	
Total Supported by Other Funds			19,751
Total Program			34,839

3.3. Public Law 85–890 Amending Organic Act of the National Bureau of Standards

Public Law 85–890
85th Congress, S. 2114
September 2, 1958

AN ACT

To amend the Act of March 3, 1901 (31 Stat. 1449), as amended, to incorporate in the Organic Act of the National Bureau of Standards the authority to acquire land for field sites, to undertake construction and improvement of buildings and for other activities.

National Bureau of Standards.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act entitled "An Act to establish the National Bureau of Standards", approved March 3, 1901, as amended, is amended by adding the following sections:

Field sites.
70 Stat. 959.
15 USC 271 *et seq.*

"SEC. 13. To the extent that funds are specifically appropriated therefor, the Secretary of Commerce is authorized to acquire land for such field sites as are necessary for the proper and efficient conduct of the activities authorized herein.

Improvements, etc.

"SEC. 14. Within the limits of funds which are appropriated for the National Bureau of Standards, the Secretary of Commerce is authorized to undertake such construction of buildings and other facilities and to make such improvements to existing buildings, grounds, and other facilities occupied or used by the National Bureau of Standards as are necessary for the proper and efficient conduct of the activities authorized herein: *Provided*, That no improvement shall be made nor shall any building be constructed under this authority at a cost in excess of $40,000 unless specific provision is made therefor in the appropriation concerned.

Functions.

"SEC. 15. In the performance of the functions of the National Bureau of Standards the Secretary of Commerce is authorized to undertake the following activities: (a) The purchase, repair, and cleaning of uniforms for guards; (b) the repair and alteration of buildings and other plant facilities; (c) the rental of field sites and laboratory, office, and warehouse space; (d) the purchase of reprints from technical journals or other periodicals and the payment of page charges for the publication of research papers and reports in such journals; (e) the furnishing of food and shelter without repayment therefor to employees of the Government at Arctic and Antarctic stations; (f) for the conduct of observations on radio propagation phenomena in the Arctic or Antarctic regions, the appointment of employees at base rates established by the Secretary of Commerce which shall not exceed such maximum rates as may be specified

72 Stat. 1711.

72 Stat. 1712.

from time to time in the appropriation concerned, and without regard to the civil service and classification laws and titles II and III of the Federal Employees Pay Act of 1945; and (g) the erection on leased property of specialized facilities and working and living quarters when the Secretary of Commerce determines that this will best serve the interests of the Government."

59 Stat. 296, 298.
68 Stat. 1109.
5 USC 911 *et seq*, 921 *et seq.*

15 USC 278a.

SEC. 2. Such Act is further amended in section 11, paragraph (a) by striking out the word "therein" and substituting therefor the word "herein".

Repeal.

SEC. 3. The Act entitled "An Act to provide authority for certain functions and activities in the Department of Commerce and for other purposes" approved July 21, 1950, is hereby repealed in its entirety.

64 Stat. 370.
15 USC 285, 286.

Approved September 2, 1958.

3.4. Advisory Committees

STATUTORY VISITING COMMITTEE

[Reports annually to Secretary of Commerce on NBS activities (Dates indicate expiration of appointment)]

Dr. M. J. Kelly, Former President and Chairman of the Board, Bell Telephone Laboratories, Inc. (1962), Chairman
Dr. Crawford H. Greenewalt, President, E. I. du Pont Nemours & Co. (1959)
Dr. Detlev W. Bronk, President, National Academy of Sciences (1960)
Professor F. Seitz, University of Illinois (1961)
Dr. Lloyd V. Berkner, President, Associated Universities Inc. (1963)

Technical Advisory Panels

[Appointed by the National Academy of Sciences-National Research Council in cooperation with the leading scientific and technical societies to advise NBS Director in specific technical areas. Cooperating societies are: American Ceramic Society (ACerS); American Chemical Society (ACS); American Institute of Chemical Engineers (AIChE); American Institute of Electrical Engineers (AIEE); American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME); American Institute of Physics (AIP); American Society of Civil Engineers (ASCE); American Society of Mechanical Engineers (ASME); Conference Organization for Mathematical Sciences (COMS); and Institute of Radio Engineers (IRE). Members listed served during fiscal year 1959]

Dean R. B. Lindsay, Brown University, Chairman, Committee of Panel Chairmen
Dr. O. F. Schuette, National Research Council, Executive Secretary

ADVISORY PANEL TO ELECTRICITY AND ELECTRONICS DIVISION

Prof. W. A. Lewis, Illinois Institute of Technology, Chairman (AIEE)
Prof. Norman I. Adams, Jr., Yale University (AIP)
Dr. John G. Brainerd, University of Pennsylvania (IRE)
Mr. H. P. Corwith, Western Union Telegraph Company (AIEE)
Mr. Robert W. Larson, General Electric Research Laboratories (AIEE)
Prof. Henry B. Linford, Columbia University (ACS)
Mr. Leon Podolsky, Sprague Electric Company (IRE)

ADVISORY PANEL TO OPTICS AND METROLOGY DIVISION

Prof. John Strong, Johns Hopkins University, Chairman (AIP)
Prof. Clarence E. Bennett, University of Maine (AIP)
Mr. Floyd W. Hough, Arlington, Virginia (ASCE)
Mr. Paul V. Miller, Taft Pierce Manufacturing Company (ASME)
Dr. Brian O'Brien, Pomfret, Conn. (AIP)

ADVISORY PANEL TO HEAT DIVISON

Prof. Mark W. Zemansky, City College of New York, Chairman (AIP)
Prof. C. Harold Berry, Belmont, Mass. (ASME)
Prof. Henry A. Fairbank, Yale University (AIP)
Dean Henry Eyring, University of Utah (ACS)
Prof. Joseph Kestlin, Brown University (ASME)
Dean R. B. Lindsay, Brown University (AIP)
Prof. J. E. Mayer, University of Chicago (ACS)
Prof. Glen C. Williams, Massachusetts Institute of Technology (AIChE)

ADVISORY PANEL TO ATOMIC AND RADIATION PHYSICS DIVISION

Prof. A. O. C. Nier, University of Minnesota, Chairman (AIP)
Prof. John Bardeen, University of Illinois (AIP)
Prof. J. W. M. DuMond, California Institute of Technology (AIP)
Dr. William A. Higinbotham, Brookhaven National Laboratory (IRE)
Prof. Polykarp Kusch, Columbia University (AIP)
Prof. Harold A. Lamonds, North Carolina State College (AIEE)
Dr. Otto Oldenberg, Harvard University (AIP)
Dr. H. M. Parker, General Electric Co. (AIP)

ADVISORY PANEL TO CHEMISTRY DIVISION

Prof. F. Daniels, University of Wisconsin, Chairman (ACS)
Prof. N. Howell Furman, Princeton University (ACS)
Prof. Hans H. Jaffe, University of Cincinnati (ACS)
Dr. J. R. Ruhoff, Malinckrodt Chemical Company (ACS)
Dr. Norman A. Shepard, Stamford, Conn. (ACS)

ADVISORY PANEL TO MECHANICS DIVISION

Dean Dana Young, Yale University, Chairman (ASME)
Prof. Lynn S. Beedle, Lehigh University (ASCE)
Prof. S. R. Beitler, Ohio State University (ASME)
Prof. A. T. Ippen, Massachusetts Institute of Technology (ASCE)
Dr. H. F. Olson, Radio Corporation of America (AIP)
Prof. Jesse Ormondroyd, University of Michigan (ASME)
Dr. Milton Plesset, California Institute of Technology (AIP)

ADVISORY PANEL TO ORGANIC AND FIBROUS MATERIALS DIVISION

Dr. Norman A. Shepard, Stamford, Conn., Chairman (ACS)
Dr. J. H. Dillon, Textile Research Institute (AIP)
Dr. Milton Harris, Harris Research Laboratory (ACS)
Prof. Herman F. Mark, Polytechnic Institute of Brooklyn (AIP)
Prof. C. S. Marvel, University of Illinois (ACS)
Dr. J. F. Downie Smith, Carrier Corporation (ASME)

ADVISORY PANEL TO METALLURGY DIVISION

Dr. Clarence Sims, Battelle Memorial Institute, Chairman (AIME)
Dr. D. J. Dienes, Brookhaven National Laboratory (AIP)
Mr. John Freeman, Jr., American Brass Company (ASME)
Dr. Maxwell Gensamer, Columbia University (ASME)
Dr. Francis L. LaQue, International Nickel Company (ACS)
Mr. Arthur R. Lytle, Electro-Metallurgical Co. (AIME)
Dean Elburt Osborn, Pennsylvania State University (ACerS)
Dr. Joseph A. Pask, University of California (ACerS)
Dr. Albert J. Phillips, American Smelting and Refining Co. (AIME)
Dr. Cyril S. Smith, University of Chicago (AIME)
Dr. E. C. Smith, Republic Steel Corporation (AIME)

ADVISORY PANEL TO MINERAL PRODUCTS DIVISION

Dean Elburt Osborn, Pennsylvania State University, Chairman (ACerS)
Mr. Herbert Insley, Washington, D.C. (ACerS)
Dr. Norbert J. Kreidl, Bausch and Lomb Optical Company (ACerS)
Mr. John T. Roberts, Ingersoll-Humphreys Division Borg-Warner (ACerS)
Prof. Pierce Selwood, Northwestern University (ACS)
Mr. Karl Schwartzwalder, General Motors Corporation (ACerS)
Dr. Robert B. Sosman, Rutgers, The State University (ACerS)
Prof. Bertram E. Warren, Massachusetts Institute of Technology (AIP)
Dr. Clarence Zener, Westinghouse Electric Corporation (AIME)

ADVISORY PANEL TO BUILDING TECHNOLOGY DIVISION

Dr. G. H. Hickox, Fort Belvoir, Va., Chairman (ASCE)
Mr. G. M. Jusinberre, Wellsboro, Pa. (ASME)
Dr. James F. Eversole, Union Carbide Development Corporation (ACS)
Mr. W. C. Hansen, Universal Atlas Cement Company (ASCE)
Prof. Robert A. Hechtman, The George Washington University (ASCE)
Mr. Paul V. Johnson, Structural Clay Products Research Foundation (ACerS)
Dean W. L. McCabe, Polytechnic Institute of Brooklyn (AIChE)
Dr. John S. Parkinson, Johns-Manville Products Corporation (AIP)
Mr. Raymond C. Reese, Toledo, Ohio (ASCE)

ADVISORY PANEL TO APPLIED MATHEMATICS DIVISION

Prof. A. H. Taub, University of Illinois, Chairman (COMS)
Prof. David Blackwell, University of California (COMS)
Dr. Alston S. Householder, Oak Ridge National Laboratory (COMS)
Prof. Mark Kac, Cornell University (COMS)
Prof. Philip M. Morse, Massachusetts Institute of Technology (COMS)
Prof. J. Walsh, Harvard University (COMS)

ADVISORY PANEL TO DATA PROCESSING SYSTEMS DIVISION

Dr. Alston S. Householder, Oak Ridge National Laboratory, Chairman (COMS)
Mr. John C. McPherson, International Business Machines Corporation (IRE)
Prof. Charles L. Miller, Massachusetts Institute of Technology (ASCE)
Prof. Raymond Pepinsky, Pennsylvania State University (AIP)
Prof. William H. Radford, Massachusetts Institute of Technology (IRE)
Mr. Morris Rubinoff, Philco Corporation (AIEE)

ADVISORY PANEL TO CRYOGENIC ENGINEERING DIVISION

Prof. Charles Squire, The Rice Institute (AIP)
Prof. S. C. Collins, Massachusetts Institute of Technology (ASME)
Mr. A. Latham, Jr., Arthur D. Little Company (AIChE)
Dr. Clyde McKinley, Air Products Incorporated (AIChE)

ADVISORY PANEL TO CENTRAL RADIO PROPAGATION LABORATORY

Prof. Henry G. Booker, Cornell University, Chairman (IRE)
Mr. Stuart L. Bailey, Washington, D.C. (IRE)
Mr. A. B. Crawford, Bell Telephone Laboratories
Dr. S. W. Herwald, Westinghouse Electric Corporation (AIEE)
Dr. John S. Smyth, Smyth Research Associates (AIP)
Prof. A. H. Waynick, National Science Foundation (IRE)
Dr. H. W. Wells, Carnegie Institution of Washington (IRE)
Prof. J. B. Wiesner, Massachusetts Institute of Technology (IRE)

ADVISORY PANEL TO RADIO STANDARDS DIVISION

Prof. E. C. Jordan, University of Illinois, Chairman (IRE)
Prof. Walter Gordy, Duke University (AIP)
Prof. W. A. Lewis, Illinois Institute of Technology (AIEE)
Prof. Arthur A. Oliner, Polytechnic Institute of Brooklyn (IRE)
Dr. John C. Simons, National Research Corporation (IRE)
Mr. Robert C. Sprague, Sprague Electric Company (AIEE)

WEIGHTS AND MEASURES ADVISORY COMMITTEE

[Members are nominated by the National Conference on Weights and Measures]

Dr. A. T. McPherson, National Bureau of Standards, Chairman
Mr. C. M. Fuller, Sealer of Weights and Measures, Los Angeles County, Calif.
Mr. W. A. Scheurer, Exact Weight Scale Company
Prof. L. J. Gordon, Weights and Measures Research Center, Dennison University
Mr. Rollin E. Meek, State Board of Health, Indiana
Commissioner P. C. Brinkley, State Department of Agriculture and Markets, Virginia
Mr. L. T. Gustafson, Creamery Package Manufacturing Company

ASA–ASTM ADVISORY COMMITTEES

For many years the National Bureau of Standards has worked in close cooperation with the American Standards Association and the American Society for Testing Materials. The committees designated by these organizations to advise the Director of the Bureau in areas of mutual interest currently are being reorganized.

3.5. Awards and Honors

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from government, academic, professional, and industrial groups. The following list reflects such recognition bestowed on Bureau staff members during the fiscal year 1959.

RECIPIENT	HONOR
Achenbach, Paul R.	Elected Fellow of the American Society of Heating, Refrigerating and Air Conditioning Engineers.
Blum, William (Retired)	William Blum Award of the Washington-Baltimore Section, Electrochemical Society.
Branscomb, Lewis M.	Physics Award of the Washington Academy of Sciences.
Brode, Wallace R. (On leave of absence)	Sixth Annual Award of the Society of Applied Spectroscopy.
Broida, Herbert P.	Senior Fellowship grant from the National Science Foundation.
Brombacher, William G.	Honorary Membership in the Instrument Society of America.
Bussey, William S.	Elected Vice President of the Institute of Weights and Measures Administration in England.
	Honorary Membership in the Southern Weights and Measures Association.
Cassel, James M.	Alsop Award of the American Leather Chemists Association.
Danos, Michael	Fellowship grant from the John Simon Guggenheim Memorial Foundation.
Davis, Marion M.	Chosen to deliver the Marie Curie Lecture for 1958 by the Pennsylvania State University Chapter of Iota Sigma Pi.
Dickinson, John A.	Arthur Williams Memorial Award of the American Museum of Safety.
Digges, Thomas G.	Burgess Memorial Award of the American Society of Metals.
Geller, Roman F.	Albert Victor Bleininger Award of the American Ceramic Society, Pittsburgh Section.
Herbstreit, Jack W.	Harry Diamond Memorial Award for 1959 of the Institute of Radio Engineers.
Hoffman, James I.	1959 Fisher Award in Analytical Chemistry of the American Chemical Society.
Kanagy, Joseph R.	Alumni Achievement Award from Westminister College.
Lide, David R., Jr.	Fellowship grant from the National Science Foundation.
Mandelkern, Leo	Arthur S. Flemming Award of the Junior Chamber of Commerce of Washington, D.C.
Meggers, William F. (Retired)	Elected Honorary Member of the Optical Society of America.
Paffenbarger, George C. (Research Associate)	1958 Callahan Gold Medal of the Ohio State Dental Association.
Parsons, Douglas E.	Henry C. Turner Medal of the American Concrete Institute.
	Honorary Life Membership in the American Society for Testing Materials.
Reinhart, Frank W.	Elected a Distinguished Member of the Society of Plastics Engineers.
Scott, Arnold H.	Award of Merit of the American Society for Testing Materials.
Scribner, Bourdon F.	1959 Award of the Spectroscopy Society of Pittsburgh.
Smith, Ralph W.	Honorary Membership in the Southern Weights and Measures Association.
Sterrett, Kay F.	Fellowship grant from Netherlands Government.
Stiehler, Robert D.	Elected President of the Washington Rubber Group.
Sweeney, William T.	Award of Merit from the St. Louis Dental Society.
Tchen, Chan-Mou	Fellowship grant from the John Simon Guggenheim Memorial Foundation.
Teele, Ray P.	Elected a Director of the Illuminating Engineering Society.

DEPARTMENT OF COMMERCE EXCEPTIONAL SERVICE AWARDS

RECIPIENT	TECHNICAL AREA
Bender, Peter L.	Atomic standards of frequency.
Driscoll, Raymond L.	Determination of atomic constants.
McPherson, Archibald T.	Leadership in calibration, testing, and specifications research.
Rhodes, Ida	Design and application of digital computing equipment.
Wait, James R.	Authorship in the field of radio wave propagation.

Infrasonics Group: Development of defense instrumentation.

Brown, Robert F., Jr.
Chrzanowski, Peter
Cordero, Fidel
Frey, Hilbert W.
Goerke, Vernon H.
Johnson, Daniel P.
Levine, Irving
Matheson, Harry

DEPARTMENT OF COMMERCE MERITORIOUS SERVICE AWARDS

RECIPIENT	TECHNICAL AREA
Bell, Rosemond K.	Chemical analysis of metals and alloys.
Blaine, Raymond L.	Science and technology of Portland cement.
Bohn, Richard A.	Cement testing.
Dalzell, Harry P.	Initiation and promotion of safety program.
Falkinburg, Francis C.	Calibration of force measuring devices.
Frush, Harriet L.	Chemistry of carbohydrates.
Heaton, Vincent E.	Maintenance of U.S. primary standard of frequency.
Hobbs, Robert B.	Science and technology of leather and paper.
Howard, Paul T.	Specifications for organic coatings.
Jean, A. Glenn	Radio propagation measurements.
Kemper, John A.	Radio propagation measurements.
Motz, Joseph W.	X-ray cross section and polarization research.
Parfitt, Isabelle C.	Administrative duties.
Scheirer, Charles E.	Cement testing.
Stansbury, Carroll	Electronic and electromechanical equipment development.
North Atlantic Radio Warning Service: Bender, Norbert Boggs, Kent D. Jones, Lawrence A. Moore, Roger C. Pritting, John W. Sullivan, John L., Jr. Weldon, James M. Wiewara, Edward J.	International Geophysical Year world warning service.

3.6. Education and Training Program

The Bureau sponsors a broad Employee Development Program oriented to the education and training needs of all staff members. Primary program objectives are increasing efficiency in the conduct of official, assigned duties, and systematic preparation for increased responsibilities. This program is implemented through two major educational media: The NBS Graduate School, and training through non-Government facilities. The program covers educational levels up through postdoctoral research and includes general staff development courses.

The curriculum of the Bureau's Graduate School, with an average of 40 courses a year, includes graduate and undergraduate courses in the physical sciences, mathematics, and certain branches of engineering; and a series of scientific colloquia and seminars led by research leaders from the Bureau staff and from other research centers in this country and abroad. Educational counseling and a program of thesis accreditation are also provided. A series of general staff development courses is also offered through the Graduate School. Typical examples in this category are scientific shorthand, mathematical symbolism and terminology, and practical metallurgy.

The Graduate School curriculum is divided into courses classed as NBS out-of-hours, NBS in-hours, and NBS university-sponsored out-of-hours. Course offerings, based on periodic need surveys, are determined by the NBS Educational Committee. The program is flexible to meet the varied and changing needs of the staff. Since the establishment of the Graduate School in 1908, more than 14,500 registrations have been recorded, and more than 260 graduate degrees have been awarded by 40 different universities, partly on the basis of credits obtained, or thesis work carried on, through the Graduate School. During the past year, there were 1,400 registrations in 78 courses offered at the Washington and Boulder Laboratories.

The Bureau sponsors three major training programs through non-government facilities under authority of the Government Employees' Training Act of 1958. These are:

1. Full-time (3–12 months) postdoctoral study and research assignments at universities and research centers, both in this country and abroad.
2. Full-time (less than 3 months) attendance at institutes, seminars, short concentrated courses, workshops, etc. Generally, these are offered through the educational facilities of major universities and industrial laboratories throughout the country.
3. Part-time, job-related, academic courses at local educational institutions, generally in early evening classes.

Approximately 190 staff members were trained through non-Government facilities in 1959. Ten selected career scientists were sent on full-time research assignments to universities and research centers. Thirty staff members, primarily scientists and subprofessional laboratory personnel, attended short concentrated courses and training programs at universities and in industry. In addition, 150 employees, mostly from technical divisions, attended job-related courses at local educational facilities. Participants' full salaries and expenses in non-Government training programs were paid by the Bureau. These included tuition, related fees, travel, and per diem, as well as transportation of family and household effects for full-time, long-term training.

An annual summer student trainee program at the Bureau is open to college students majoring in the physical sciences, mathematics, and certain branches of engineering. This activity is an integrated work-study program including lectures, tours, demonstrations, supervised laboratory assignments, and professional counseling. The program has the twofold purpose of acquainting young people with career opportunities in scientific research at NBS and preparing select students for such careers. The 1959 summer student program had an enrollment of 160 students, with 69 new students, and 91 returnees from previous summers. The new group included 13 outstanding high school students who had obtained recognition through the Westinghouse Science Talent Search or other national science competition. Approximately 40 percent of the 1959 total enrollment were graduate students who returned to school in September to undertake advanced study programs. The 1959 student group represented 46 colleges and universities from a wide geographical area.

In collaboration with the National Research Council, the Graduate School offers postdoctoral resident research associateships to young scientific investigators of unusual ability and promise of becoming creative leaders in basic research. Associates are given an opportunity for advanced training in basic research in the various branches of the physical and mathematical sciences. While acquiring basic knowledge, they have opportunities for developing new scientific approaches and laboratory skills, thus advancing

scientific knowledge. Associateships, which are limited to 20 at any one time, are tenable at both the Washington and Boulder Laboratories.

The Bureau's educational program also includes weekly Scientific Staff Meetings which run from September through May. Of less specialized nature than colloquia and seminars offered in the Graduate School, the Scientific Staff Meetings are open to all members of the professional staff at the Bureau and are also regularly attended by scientific personnel from neighboring laboratories. Designed to keep Bureau personnel abreast of current developments in the various fields, these lectures are given by members of the staff and by scientists from universities and other laboratories in the United States and abroad. Lectures by members of the Bureau staff include a yearly report to the staff by the Director, lectures on current research of broad general interest to other members of the staff, reports by staff members on international meetings, and reports from fellowship scientists on research work at other institutions in this country and abroad. About two-thirds of the program is devoted to lectures by guest scientists.

3.7. Cooperative Research With Industry

The Bureau's Research Associate Plan, a cooperative program with American industry, has resulted in many significant developments in science and technology. Under this plan, technical, industrial, and commercial organizations can support work at the Bureau on projects that are of special interest to them, yet are of sufficient general interest to justify use of government facilities. These projects must also be important from the standpoint of the Nation's sum total of technological knowledge. Supporting industries donate both funds and personnel for the projects. At the present time 12 groups are supporting research associates at NBS in the following areas:

Sponsor	*Field of Activity*
American Dental Association	Dental research.
American Electroplaters Society	Porosity and corrosion of electroplated surfaces.
American Society for Testing Materials	Cement reference laboratory.
American Society for Testing Materials	Completion of spectral data.
Asphalt Roofing Industry Bureau	Asphalt roofing research.
Bone Char Research Project, Inc	Studies of adsorption and adsorbents.
Calcium Chloride Association	Hydration of portland cement.
NBS-Joint Committee on Chemical Analysis by Powder Diffraction Methods: ASTM, American Crystallographic Assoc., Institute of Physics (British), National Assoc. of Corrosion Engineers.	Standard X-ray diffraction powder patterns.
National Research Council	Masonry research.
Porcelain Enamel Institute	Development of standard tests.
Portland Cement Association	Basic research in physical chemistry related to portland cement.

An important and similar area of cooperation between the Bureau and industry is the program authorized in 1950 by Public Law 619 under which the Bureau is authorized to accept funds for the purpose of furthering its work. This arrangement permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public.

During the past year 18 projects were supported by gifts from 32 organizations as follows:

Gift-Supported Projects

Donor	*Field of Activity*
American Iron and Steel Institute	Standard samples of ferrous metals, steel research.
American Iron and Steel Institute	Bond tests on high yield point reinforcing bars.
American Petroleum Institute	Metal-organic analytical standards.
Brown and Sharpe Manufacturing Company	Precision Gage Block Program.
Carnegie Institute	Telescope image tubes.
CBS Television	Television Field Strength Studies.
Corrosion Research Council of the Engineering Foundation.	Reactions at Metal Surfaces and Stress Corrosion.
Dearborn Gage Company	Precision Gage Block Program.
Do-All Company	Precision Gage Block Program.
E. I. du Pont de Nemours & Company, Inc	Precision Gage Block Program.
Edward Orton Ceramic Foundation	Research in clays.
Expanded Shale Clay and Slate Institute	Creep and Shrinkage of Concrete Containing Expanded Shale Aggregate.
Fonda Gage Company, Inc	Precision Gage Block Program.
General Electric Company	Precision Gage Block Program.
Georgetown University	Physiological Research.
Greenfield Tap and Die Corporation	Precision Gage Block Program.
Hughes Aircraft	Precision Gage Block Program.
IBM Corporation	Precision Gage Block Program.
Illuminating Engineering Research Institute	Programing computers for calculating the chromaticity coordinates with lamps having line spectra.
International Nickel Company	Effect of Nickel on Thermal Conductivity of Steel.
Link Aviation, Inc	Precision Gage Block Program.
National Lime Association	Hydration of Lime.
New Departure, GMC	Precision Gage Block Program.
Pratt and Whitney Company	Precision Gage Block Program.
The Sheffield Corporation	Precision Gage Block Program.
Sugar Research Council	Indices of Solutions of Invert Sugars.
Taft-Peirce Foundation	Precision Gage Block Program.
Technical Association of the Pulp and Paper Industry.	Relationship and Sensitivity of Air Leak Smoothness Testers.
Timken Roller Bearing Company	Precision Gage Block Program.
UNESCO	Ionization chamber.
The Van Keuren Company	Precision Gage Block Program.
Welding Research Council of the Engineering Foundation.	Stress-corrosion cracking of stainless steel.
Anonymous	Phenomena of crystallization.

3.8. Publications*

Publications in the Bureau's Series

Journal of Research. Complete scientific reports of the Bureau's research and development, both experimental and theoretical, in physics, chemistry, engineering, and mathematics, and the results of test and instrumentation activities in these fields are printed in the *Journal.* (The papers listed below complete the monthly *Journal of Research* ending June 1959. The *Journal of Research* is now issued in four sections; for additional information, see p. 15 and inside back cover.)

Volume 61, July–December 1958

2877. The system lime-alumina-water at 1° C. Elmer T. Carlson.
2878. Heat content of zirconium and of five compositions of zirconium hydride from 0° to 900° C. Thomas B. Douglas and Andrew C. Victor.
2879. Uniform transient error. Edith L. R. Corliss.
2880. Optical T-bench method of measuring longitudinal spherical aberration. Francis E. Washer.
2881. Mass spectrometric study of the rate of thermal decomposition of hydrazoic acid. J. L. Franklin, Vernon H. Dibeler, and Preston P. Morris, Jr.
2882. Erosion damage to solids caused by high-speed collision with rain. Olive G. Engel.
2883. Emission spectrum of carbon monoxide from 2.3 to 2.5 microns. Earle K. Plyler, Harry C. Allen, Jr., and Eugene D. Tidwell.
2884. Further studies on the influence of a ridge on the low-frequency ground wave. James R. Wait and Anabeth Murphy.
2885. Infrared studies of polymorphs of silicon dioxide and germanium dioxide. Ellis R. Lippincott, Alvin Van Valkinburg, Charles E. Weir, and Elmer N. Bunting.
2886. Carbon-14 carboxy-labeled polysaccharides. Joseph D. Moyer and Horace S. Isbell.
2887. Heat of formation of sodium calcium aluminate. Edwin S. Newman.
2888. Thermal degradation of polyacrylonitrile, polybutadiene, and copolymers of butadiene with acrylonitrile and styrene. Sidney Straus and Samuel L. Madorsky.
2889. On the motion of two cylinders in an ideal fluid. Lloyd H. Carpenter.
2890. Properties of sodium titanium silicate glasses. Edgar H. Hamilton and Given W. Cleek.
2891. Wavelengths from thorium-halide lamps. William F. Meggers and Robert W. Stanley.
2892. An electrical-analog method for transient heat-flow analysis. A. F. Robertson and Daniel Gross.
2893. Effect of crystal field and spin-orbit coupling on magnetic susceptibility of systems with f^2 electron configuration. Charles M. Herzfeld and Daniel B. Levine.
2894. Vibration-rotation bands of ammonia: 1. The combination bands $\nu_2+(\nu_1,\nu_3)$. William S. Benedict, Earle K. Plyler, and Eugene D. Tidwell.
2895. Evaluation of tensile, compression, torsional, transverse, and impact tests and correlation of results for brittle cermets. Matthew J. Kerper, Lewis E. Mong, Maurice B. Stiefel, and Sylvanus F. Holley.
2896. Redetermination of mass spectra of deuteromethanes. Fred L. Mohler, Vernon H. Dibeler, and Edith Quinn.
2897. Effect of strain-temperature history on the tensile behavior of titanium and a titanium alloy. Glenn W. Geil and Nesbit L. Carwile.
2898. Propagation of very-low-frequency pulses to great distances. James R. Wait.
2899. Transmission and reflection of electromagnetic waves in the presence of stratified media. James R. Wait.
2900. Pseudoternary system calcium oxide-monocalcium aluminate ($CaO \cdot Al_2O_3$)-dicalcium ferrite ($2CaO \cdot Fe_2O_3$). Terry F. Newkirk and R. D. Thwaite.
2901. Heats of formation of diborane and pentaborane. Edward J. Prosen, Walter H. Johnson, and Florence Y. Pergiel.
2902. Temperature of the inversion in cristobalite. Raymond F. Walker, Samuel Zerfoss, Sylvanus F. Holley, and Lucy J. Gross.
2903. Infrared emission spectra of flames under high resolution. Earle K. Plyler, and Eugene D. Tidwell.
2904. Improved description of hafnium spectra. Charles H. Corliss and William F. Meggers.
2905. Dielectric constant of hydrogen-bonded liquids. Floyd Buckley.
2906. On the diffraction and reflection of waves and pulses by wedges and corners. F. Oberhettinger.

*Publications in these series are available, unless otherwise indicated, from the Superintendent of Documents, Washington 25, D.C.

2907. A liquid-helium cold cell for use with an X-ray diffractometer. Igor A. Black, Leonard H. Bolz, Frank P. Brooks, Floyd A. Mauer, and H. Steffen Peiser.
2908. The second spectrum of ruthenium (Ru II). Allen G. Shenstone and William F. Meggers.
2909. Self-ignition temperatures of materials from kinetic-reaction data. Daniel Gross and A. F. Robertson.
2910. Some studies of atmospheric transmittance on Mauna Loa. Ralph Stair and Russell G. Johnston.
2911. Central notations for the revised ISCC–NBS color-name blocks. Kenneth L. Kelly.
2912. Viscosity of *n*-hexadecane. Robert C. Hardy.
2913. Revision of the phase equilibrium diagram of the binary system calcia-titania, showing the compound $Ca_4Ti_3O_{10}$. Robert S. Roth.
2914. Term analysis of the second spectrum of rhenium (Re II). William F. Meggers, Miguel A. Catalán, and Manuel Sales.
2915. Density formula for alkali silicate glasses from annealing to glass-processing temperatures. Leroy W. Tilton.
2916. Thermodynamic properties of gases at high temperature: 1. Chemical equilibrium among molecules, atoms, and atomic ions considered as clusters. Harold W. Woolley.
2917. Parallel testing interferometer. James B. Saunders.
2918. Correction for instrumental drift in flame photometry. Barry W. Mulligan and Alan F. Haught.
2919. Mechanism of stress-corrosion cracking in the AZ31B magnesium alloy. Hugh L. Logan.
2920. Evaluation of lens distortion by visual and photographic methods. Francis E. Washer, William P. Tayman, and Walter R. Darling.

Volume 62, January–June 1959

2921. Heat of mixing of polybutadiene and benzene. Ralph S. Jessup.
2922. Infrared high resolution grating spectrometer. Earle K. Plyler and Lamdin R. Blaine.
2923. Determination of titanium, zirconium, nobium, and tantalum in steels: Separations by anion-exchange. John L. Hague and Lawrence A. Machlan.
2924. Preparation of new solution standards of radium. W. B. Mann, L. L. Stockmann, W. J. Youden, A. Schwebel, P. A. Mullen, and S. B. Garfinkel.
2925. Phase equilibrium relations in the binary system lead oxide-niobium pentoxide. Robert S. Roth.
2926. Mass spectra of some deuterostyrenes. Edith I. Quinn and Fred L. Mohler.
2927. Heat of reaction of diborane with water and the heat of formation of boric oxide. Edward J. Prosen, Walter H. Johnson, and Florence Y. Pergiel.
2928. Heat of formation of titanium tetrachloride. Walter H. Johnson, Raymond A. Nelson, and Edward J. Prosen.
2929. Determination of niobium and tantalum in titanium-base alloys. John L. Hague and Lawrence A. Machlan.
2930. Properties of zinc borosilicate glasses. Edgar H. Hamilton, Roy M. Waxler, and Joseph M. Nivert, Jr.
2931. Design and performance of a block-type osmometer. Donald McIntyre, G. C. Doderer, and James H. O'Mara.
2932. Heat of formation of titanium tetrabromide. Raymond A. Nelson, Walter H. Johnson, and Edward J. Prosen.
2933. Adsorption of polyesters on glass, silica, and alumina. Robert R. Stromberg, Alan R. Quasius, Samuel D. Toner, and Midgett S. Parker.
2934. Theory of the effect of drag on the orbital inclination of an earth satellite. John P. Vinti.
2935. On a theorem of M. Riesz. Martin Pearl.
2936. Refinement of the crystal structure of triclinic magnesium pyroborate. Stanley Block, Gordon Burley, Alvin Perloff, and Robert D. Mason, Jr.
2937. Heat transfer in laminar flow through a tube. Milton Abramowitz, William F. Cahill, and Clarence Wade, Jr.
2938. Fluorination of haloaromatic compounds. Roland E. Florin, Walter J. Pummer, and Leo A. Wall.
2939. Synthesis of some disubstituted 3,4,5,6-tetrafluorobenzenes. Walter J. Pummer, Roland E. Florin, and Leo A. Wall.
2940. Reactions of aromatic fluorocarbons with hydrogen. Roland E. Florin, Walter J. Pummer, and Leo A. Wall.
2941. Exponential integral $\int_1^\infty e^{-xt}t^{-n}dt$ for large values of n. Walter Gautschi.

2942. Effect of oxygen on the bonding of gold to fused silica. D. G. Moore and H. R. Thornton.
2943. Interferometer for large surfaces. James B. Saunders and Franz L. Gross.
2944. Glass formation in polymers: II. The systerm rubber-sulfur. Gordon M. Martin and Leo Mandelkern.
2945. Elastic deformations in strips with holes loaded through pins. Michael Chi and L. K. Irwin.
2946. Absolute light-scattering photometer: I. Design and operation. Donald McIntyre and G. C. Doderer.
2947. Resolution of the dissociation constants of *d,l*-malic acid from 0° to 50° C. Murray Eden and Roger G. Bates.
2948. Capacity requirement of a mail sorting device. B. K. Bender and A. J. Goldman.
2949. Effect of internal radiant heat transfer on temperature distribution, thermal stress, and deflection in box beams. Stanley Goodman, Stanton B. Russell, and Charles E. Noble.
2950. Mean absolute value and standard deviation of the phase of a constant vector plus a Rayleigh-distributed vector. J. Ralph Johler and Lillie C. Walters.
2951. A simple rotating molecular still. Gaylon S. Ross and Lois J. Frolen.
2952. Scintillation counter method of intercomparing neutron source strengths by means of a manganous sulfate bath. Earl R. Mosburg, Jr.
2953. Phase equilibria in the subsystem barium disilicate—dibarium trislicate. Robert S. Roth and Ernest M. Levin.
2954. Separation and determination of phosphate, silicate, and arsenate. W. Stanley Clabaugh and Audrey Jackson.
2955. Heat of formation of potassium calcium silicate. Edwin S. Newman.
2956. Heat of formation of boron trichloride. Walter H. Johnson, Richard G. Miller, and Edward J. Prosen.
2957. Thermal degradation of polymers at low rates. Samuel L. Madorsky.
2958. Pits in metals caused by collision with liquid drops and soft metal spheres. Olive G. Engel.
2959. Earth currents near a monopole antenna with symmetrical top loading. James R. Wait.
2960. Infrared absorption spectra of some cyclic acetals of sugars. R. Stuart Tipson, Horace S. Isbell, and James E. Stewart.
2961. Earth currents near a top-loaded monopole antenna with special regard to electrically small L- and T-antennas. H. Lottrup Knudsen.

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Patents

The following U.S. patents have been granted to NBS inventors; assigned (or licensed as indicated) to the United States of America, as represented by the Secretary of the department noted in parentheses:

Astin, Allen V., No. 2,877,452, March 10, 1959. Telemetering transmitter for a projectile. (Navy.)
Bennett, John A., and Burnett, Harry C., No. 2,844,958, July 29, 1958. Torsion fatigue testing machine for wire. (Army.)

Bennett, John A., and Burnett, Harry C., No. 2,856,769, October 21, 1958. Torsion testing machine for wire. (Army.)

Birmingham, Bascom W., Brown, Edmund H., Scott, Russell B., and Vander Arend, Peter C., No. 2,871,042, January 27, 1959. Supporting and heat insulating means. (Atomic Energy Commission.)

Boggs, Gail E., No. 2,883,527, April 21, 1959. Stabilized nonlinear amplifiers. (Commerce.)

Brenner, Abner, and Bish, Joseph, No. 2,852,533, September 16, 1958. Titanium borohydride complex and preparation thereof. (Air Force.)

Broida, Herbert P., and Pellam, John R., No. 2,892,766, June 30, 1959. Formation and stabilization of atoms and free radicals. (Commerce.)

Crane, Clarence B., No. 2,882,822, April 21, 1959. Fuze housing. (Navy.)

Davidson, Martin, and Rahal, Nicholas S., No. 2,854,626, September 30, 1958. Plating thickness indicator. (Navy.)

Davis, William W., No. 2,853,649, September 23, 1958. Williams memory system using a double-intensity beam. (Commerce.)

Eichberg, Robert L., No. 2,879,657, March 31, 1959. Combination locks. (Licensed to Commerce.)

Harmon, E'lise F., No. 2,844,172, July 22, 1958. Silk screen stretcher. (Army.)

Henderson, Joseph E., No. 2,892,093, June 23, 1959. Fuze. (Navy.)

Henig, Seymour, No. 2,863,574, December 9, 1958. Mail separator. (Commerce.)

Henry, Robert L., Jr., No. 2,843,263, July 15, 1958. Wafer gager. (Navy.)

Henry, Robert L., Jr., No. 2,892,129, June 23, 1959. Electronic module mounting device. (Navy.)

Hewitt, Clifford A., No. 2,854,992, October 7, 1958. Flow control apparatus for reaction columns and the like. (Commerce.)

Hinman, Wilbur S., Jr., and Diamond, Harry, No. 2,856,852, October 21, 1958. Proximity fuze. (Navy.)

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Huntoon, Robert D., No. 2,872,867, February 10, 1959. Ordnance construction. (Navy.)

Jaffe, Bernard, Roth, Robert S., and Marzullo, Samuel, No. 2,849,404, August 26, 1958. Morphotropic piezoelectric ceramics. (Army.)

Kissinger, Charles W., No. 2,849,629, August 26, 1958. Chatter accelerometer. (Commerce.)

Kuder, Milton L., No. 2,870,436, January 20, 1959. Electronic analogue-to-digital converter. (Commerce.)

Kuder, Milton L., No. 2,871,351, January 27, 1959. Balance detector used in electronic analogue-to-digital converter. (Commerce.)

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Mann, Douglas, and Macinko, John, No. 2,871,669, February 3, 1959. Radiation shield circulation system for large liquefied gas storage containers. (Navy.)

Marzetta, Louis A., No. 2,871,432, January 27, 1959. Automatic tracking proximity gage. (Commerce.)

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Moore, Dwight G., No. 2,857,292, October 21, 1958. Process for applying protective metallic coatings. (Air Force.)

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Rayburn, Charles C., and Henry, Robert L., No. 2,887,622, May 19, 1959. Electrical circuit pattern tester. (Navy.)

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Rosenberg, Samuel J., and Irish, Carolyn R., No. 2,863,763, December 9, 1958. Ductile and tough high-strength steel. (Navy.)

Russell, Henry H., No. 2,882,038, April 14, 1959. Large-capacity balance. (Commerce.)

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Scal, Robert K-F, and Lindseth, Clinton O., No. 2,889,493, June 2, 1959. Miniature radar assembly. (Navy.)

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